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Vol. 3. No. 8 | Pittsburgh, Pa. | August, 1930

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Handbook of Industrial Instruments — M. F. Béhar

◆

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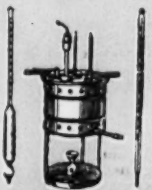

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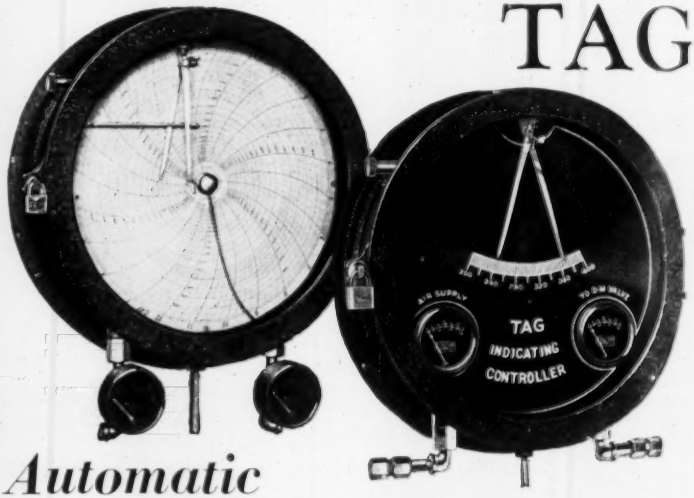


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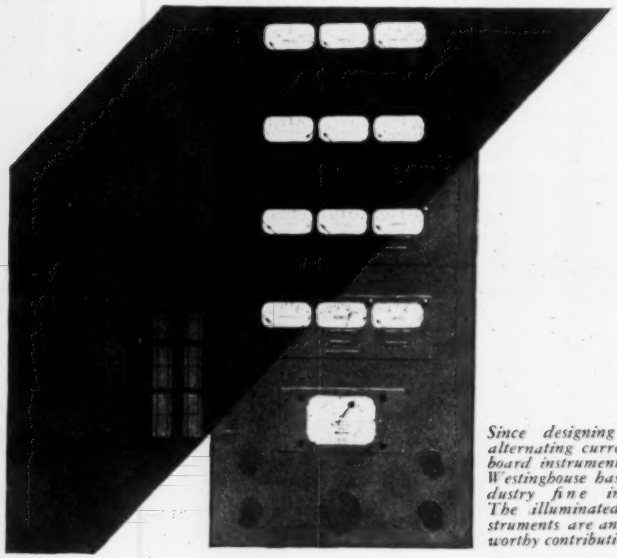

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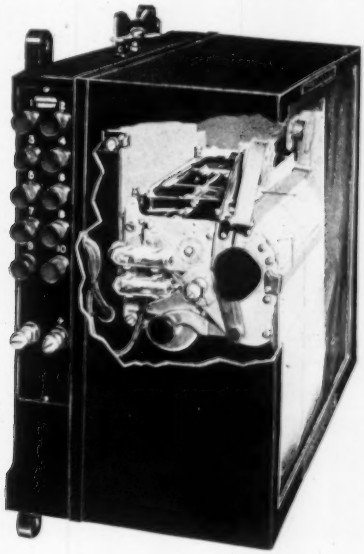

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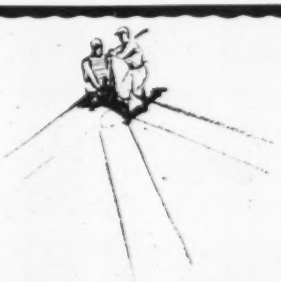

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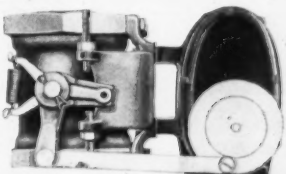

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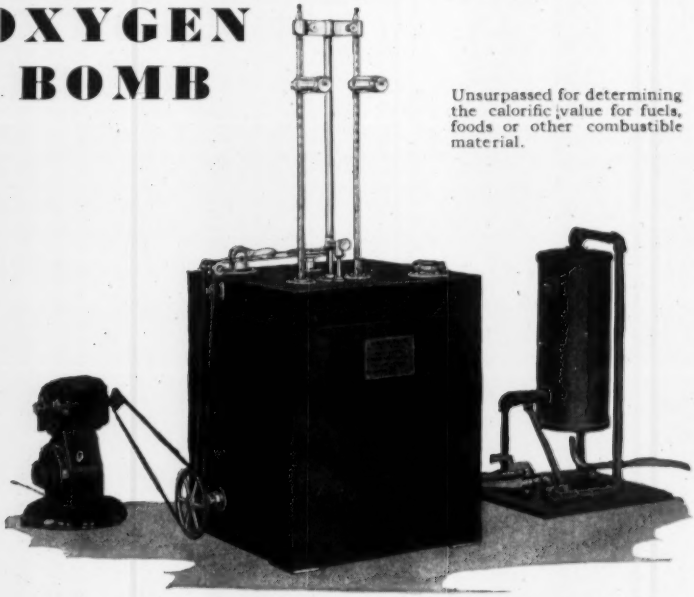

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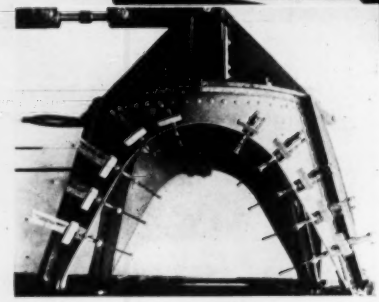

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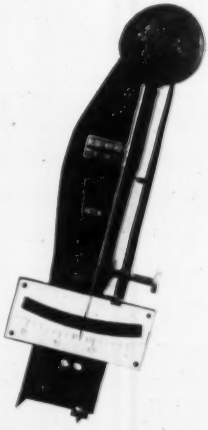

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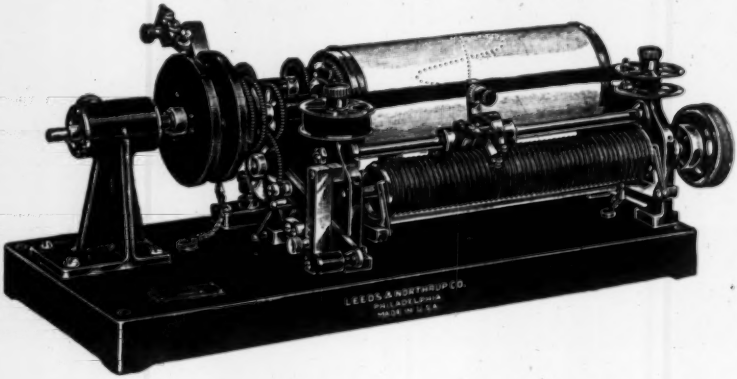


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Vol. 3, No. 8 AUGUST, 1930 Pittsburgh, Pa.


## To Our Readers

EXACTLY three years ago the work on INSTRUMENTS was actively started. Since that time the demands placed on us by the readers have steadily increased. Our offices have steadily grown in spite of business conditions, and now after three years we have again enlarged our offices, this time locating most conveniently to the sources of information.

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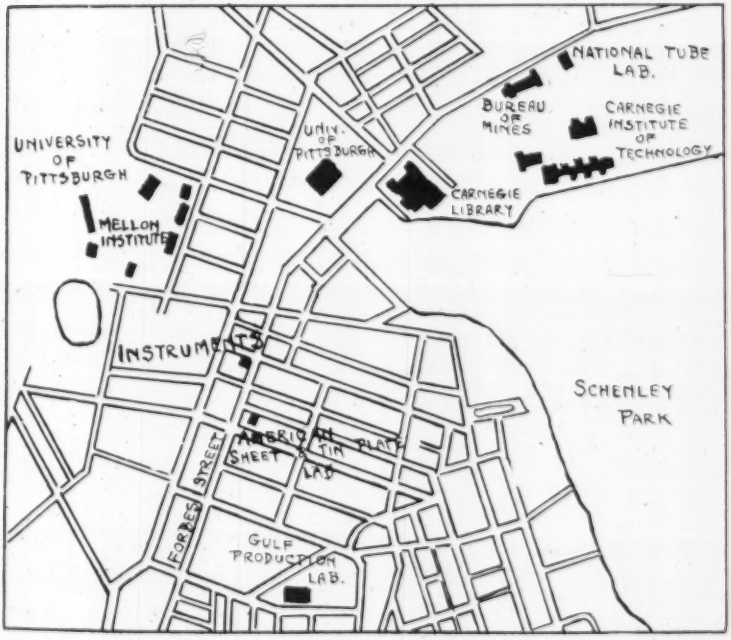

# How Hair Springs Are Made

*Henry Sugden*

THE experimental instrument maker very frequently has occasion to use a special hairspring in the instrument which he is developing, and it being very unlikely that the manufacturer will have the exact spring desired—as regards dimensions, torque, conductivity, etc., also the time required in correspondence, and shipment—he usually depends upon his own resources to make the spring himself. Besides, as the experimenter usually requires only a few springs of one kind, the manufacturer can hardly be expected to bother with such small lots. He, therefore, proceeds to rig up the necessary tools for this purpose—which do not differ very greatly from those of the manufacturer—the main difference being, that they are intended to wind only a few springs at a time; while those of the manufacturer wind large quantities at a time. The experimenter being supplied with phosphor bronze wire of various sizes, a draw-plate, a Bunsen burner and jewellers rolls, all he requires is a winding tool, which is herewith illustrated. If the instrument for which the spring is needed, be of the voltage measuring type, the spring may be of a high resistance spring material, of any diameter suitable to the space in which it must go, and of any cross-section that will produce the desired torque—this torque he knows from tests on previous springs.

If the instrument is of the millivoltmeter type, the spring resistance must be as low as possible; which means it must be short, wide and thin—always remembering that the ratio length/thickness does not fall below 1500. Also the material must be of high conductivity bronze. Having then, determined the width and outside diameter of spring, he proceeds to make the winding tool.

From a piece of soft steel or brass rod about $\frac{1}{16}''$ larger in diameter than the outside diameter of spring, cut off about $\frac{1}{2}$ inch. Chuck this piece in the lathe, drill a hole in the center, the size of the inside diameter of spring. After facing the end, make a recess equal to the outside diameter of the spring, and slightly deeper than the width of the spring. This we will call the winding block. (Fig. 1.).

Then take a piece of steel or brass rod, somewhat larger in diameter than the hole in the block. Chuck this rod and turn down one end until it fits the center hole of block snugly and projects even with face of block. Drill a hole in the end of this rod $\frac{1}{16}''$ smaller in diameter than the hole in the block, and about $\frac{1}{4}''$ deep. (Fig. 2.). This leaves a wall $\frac{1}{32}''$ thick, the same as the wall around the end of the block. These two walls now are slotted to the depth of recess in block—and divided into eight slots—with saw about 0.005″ thick for spindle wall and 0.01″ thick for block wall. The slots in block wall must be at an angle of about 45° to a radial line. (Fig. 3.)

If the block be made of brass, then a piece of steel rod should be set in as at S (Fig. 1) to be used in tempering the springs as hereafter described.

Now get a piece of board about 12″ square and $\frac{3}{4}''$ thick, and drill a hole in the center to clear the thick part of spindle, and recess with counterbore size of block $\frac{1}{4}''$ deep.

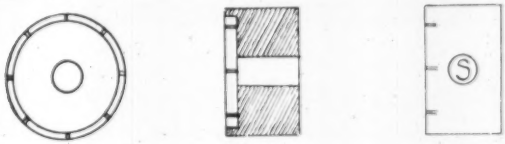


FIG. 1

FIG. 2

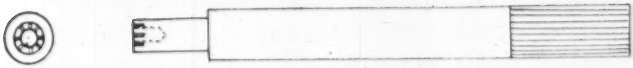

FIG. 3A

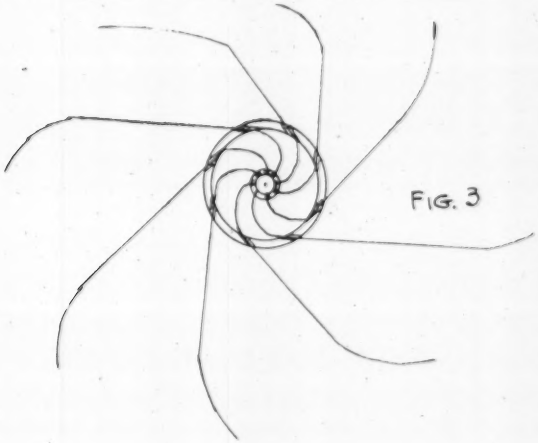

FIG. 3

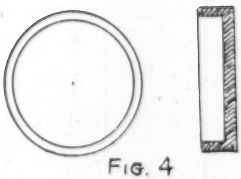

FIG. 4

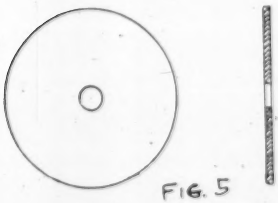

FIG. 5

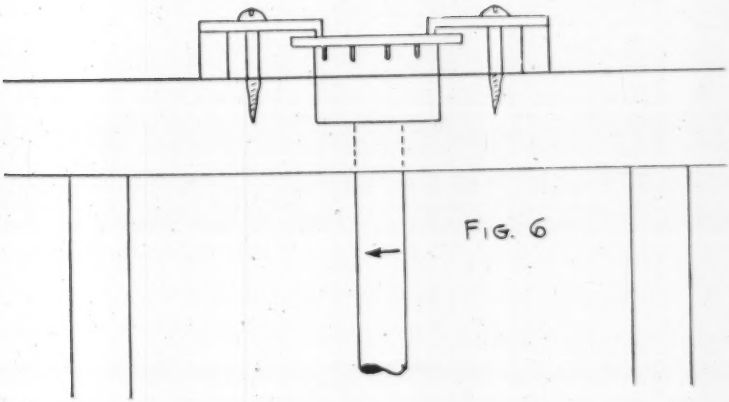

FIG. 6

Then at each corner of board, nail on legs about 9″ high, and stand it on the bench. Now we are ready to wind in the spring ribbon.

Roll down the phosphor-bronze wire to the desired thickness and width, then cut into lengths sufficient for one spring.

If one ribbon per slot be used, the distance between turns will be the thickness of ribbon multiplied by the number slots. If that is not sufficient, then two or more ribbons may be inserted in each slot.

Now put block with its spindle, in recess of board and introduce ribbons into slots in spindle, and fold back against inner wall; then continue ribbons into slots in wall of block, as shown in Fig. 3. The board is to support the ribbons.

When all ribbons are in their place, insert plug 3A in end of spindle, to prevent ribbons from coming out. Cover with disc Fig. 5 and clamp the whole board as in Fig. 6.

Turn the spindle underneath board counter-clockwise, or in a direction to move the ribbon in the direction of oblique slots in block. Keep on turning until it is felt that the recess is full. Clip off surplus ends and wind entirely in; then cover with cap (Fig. 4) and release block with its spindle from board; it is now ready for tempering.

Polish the piece of steel S, with fine emery paper without touching it with the bare fingers.

Put the block in a Bunsen flame, holding it by the spindle with a pair of pliers. Move it, watching the piece of steel S all the time for the color. When the color has reached a light blue—about 600° F., withdraw it from the flame and lay aside to cool. When thoroughly cool, take off cap, withdraw spindle and shake out the bunch of springs, these will be closely bound together, and may be separated with tweezers applied at inside ends, one at a time.

It should be mentioned that before inserting ribbons in block, they should be cleaned with gasoline and clean rag to free them from greasy finger marks; otherwise they will stick together when separating.

If the springs are not of the proper torque, others may be rolled from the same wire, and the thickness only varied to suit; remembering that the torque is proportional to the cube of thickness, other things being equal.

## W. W. PATRICK

Mr. W. W. Patrick, a director of The Foxboro Company died suddenly, July eleventh, of pneumonia. He was one of the most widely known figures in the instrument business.

He has been associated with the founders of The Foxboro Company since 1899. In 1908, he became New York District Sales Manager and held that post for twenty-two years.

Mr. Patrick was also a prominent figure in the Association of Scientific Apparatus Makers of America. He was a director of the Association and Chairman of the Industrial Instrument section.

# Instrument Repair and Standardization Laboratory

C. E. Fry*

THE Testing Department of the Westinghouse Electric and Manufacturing Company at East Pittsburgh maintains an Instrument Repair and Standardization Laboratory for the purpose of making periodic calibration and repairs to all electric instruments used in the various departments of the company. In this laboratory at the present time there are approximately 675 d.c. and 850 a.c. instruments. All d.c. instruments are calibrated once each month and the a.c. instruments are calibrated twice each month, while at the same time the necessary renewals and repairs are made to keep them in good mechanical and electrical condition.

By a system established in the laboratory, the instruments are all scheduled to be calibrated on a certain assigned date. In order to avoid confusion of having several instruments of the same rating and from the same department in the laboratory at one time, it was found necessary to consider each department separately and all instruments of the same rating at one time when fixing the testing dates. That is, if there are in a department three ten-ampere ammeters which should be tested once a month, they are given dates ten days apart; and, since the weeks do not always end on the same date, it is necessary to have a weekly schedule made in the laboratory and sent to each department with the serial number of the instruments, and the exact date on which it is to come in for calibration. Instruments are carried to and from the laboratory in an especially constructed rubber-tired truck.

All new instruments are given an acceptance test before they are put into service. This test consists of a close inspection for friction, zero indication of pointer, balance, cold and hot calibration to determine temperature error, and calibration error. If the instrument meets the approved guarantee of the supplier, a serial card record is made, and a calibration date assigned; it is then ready for service.

All types and models of instruments and instrument transformers are calibrated; among the most common are d.c. voltmeters, ammeters, and millivoltmeters; a.c. voltmeters, ammeters, and wattmeters; and resistance measuring devices. The voltmeters, ammeters and millivoltmeters may be calibrated by comparison with a standard instrument, or by the potentiometer method. In the former case the standard instrument and the one being checked are connected in multiple across the E. M. F. at the same point and their readings compared; by the potentiometer, which is a *Nil Method*, no current is used by the Standard. To those familiar with electrical measurements, it is well known that the latter method is capable of greater accuracy.

It has been the custom for some time to calibrate all d.c. instruments on five cardinal points and all a.c. instruments on seven cardinal points. After the calibration report is made and properly recorded on the instrument calibration record card (Fig. 1), the instrument is again ready to be sent to the Test Department.

The repairs made to instruments in the laboratory consist generally of renewing defective parts, such as burned springs, conducting strips, moving

*Foreman, Instrument Repair and Standardization Laboratory, Westinghouse Electric & Manufacturing Company.

elements and stationary coils, or polishing pivots and replacing cracked jewels.

When new springs are put in an instrument, great care is exercised in the soldering, as overheating a spring relieves the temper and in turn will not allow the instrument to hold its calibration.

Moving elements and stationary coils are sometimes replaced without any great change in calibration, this being true only when the new coils have the same shape and electrical characteristics such as the ones they replaced.

When the pivots are damaged it is usually caused by a sudden jar of the instrument or by a heavy overload causing the pointer to whip over against the stop at the end of the scale, leaving the pivot with a hook on the end; that is, an overturned point. This hook is removed by grinding with a fine oil stone and finishing with rouge paper, leaving a highly polished point, the polished surface being necessary to reduce friction as much as possible. Instruments are used either in a vertical or horizontal position and the pivots should be ground accordingly, that is, portable instrument pivots, which are vertical, are ground to a fine point, whereas switchboard instrument pivots, used in an horizontal position, are ground with a slightly rounded point.

Saphire jewels are most commonly used in all electrical instruments for bearings on which the pivots ride; and quite frequently they are cracked by rough handling, necessitating their replacement by new ones.

The Standards used by the Testing Laboratory are given special attention, by careful handling, by maintaining a constant room temperature, and by periodic calibration. Careful handling is very essential because it prevents excessive friction in the moving mechanism and keeps the instrument in good operating condition. When the room temperature is kept constant most temperature errors are reduced to a minimum.

All standards are standardized periodically in order to insure a correct calibration. This is done in the Standards Laboratory of the Research Engineering Department, where primary standards are kept for standardizing purposes only. The standards are used for standardizing instruments such as voltmeters, ammeters, wattmeters, inductometers, thermometers, optical pyrometers, pyrometers, potentiometers, bridges, condensers, shunts and standard cells. These standards are periodically sent to the Bureau of Standards for standardization.

The laboratory is also equipped to test instrument transformers both current and potential. Ratio and phase angle tests are made with the use of a Silsbee transformer testing set and phase shifter. It is also necessary to have a set of calibrated transformers which are used in conjunction with the Silsbee set. Any good grade of commercial transformer can be calibrated for use with this testing set. Tests made by this method can be relied upon within .1% accuracy in ratio and 5 minutes in phase angle on both 25 and 60 cycles. Each of our standard transformers carry with it a certificate of standardization from the Bureau of Standards.

This Testing Department maintains electrical measuring instruments for use in making field tests for customers. There are several complete sets of instruments and transformers available for work of this kind. These instruments are not used for any commercial or experimental testing in the factory, and are not handled except when the field test engineer is about to go out on a test, at which time these instruments are carried to the Meter Laboratory and calibrations are made. A certificate of calibration for each

instrument and transformer is supplied to the engineer in charge of the field test.

Occasionally customers prefer to have the instruments calibrated by a disinterested party, in which case the customer names the electrical laboratory in which he prefers these calibrations made. However, these instruments are always calibrated in our Laboratory in addition to being calibrated in the laboratory named by the customer. Our calibration certificates in this case are not sent with the instruments. It is quite interesting to know that by comparing calibrations made by other laboratories with our calibrations, the errors do not exceed .2% variation, and that our calibration on transformers has always been even closer due to the greater number of calibration points.

Samples of resistance wire, copper rods, and sheet material used in the manufacture of electrical apparatus are sent to the laboratory where they

SERIAL NO. 800639 — TESTING DEPARTMENT—INSTRUMENT CALIBRATION RECORD CARD — CAL. DATE 8

INSTRUMENT: D.C. AMMETER — TYPE-MODEL: PI-8 — MAKE: WESTINGHOUSE — MULT. — RATING: 8-10 Amp, Volt — PROP. OF E-27

| Date of Test | Res. M.V. Drop | Tester | Scale | | | | | | | Condition When Received / Remarks / Remarks | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 0 | 2 | 4 | 6 | 8 | 10 | | |
| | | | | | .4 | .8 | 1.2 | 1.6 | 2 | | |
| 1928 | | | | | | | | | | | |
| 4-26 | | H.W. | 77641 | 0 | 2.000 | 4.010 | 6.010 | 8.000 | 9.990 | | .35 High |
| | | | | | | Scale | Ratio | OK | | | Readjusted |
| 6-5 | | H.W. | 77641 | 0 | 2.005 | 4.015 | 6.010 | 8.000 | 10.00 | | OK |
| | | | | | | Scale | Ratio | OK | | | |
| 7-3 | | H.W. | 77641 | 0 | 2.000 | 4.030 | 6.020 | 8.000 | 10.00 | | .35 low |
| | | | | | | Scale | Ratio | OK | | | Readjusted |
| 8-7 | | H.W. | 77641 | 0 | 2.000 | 4.010 | 6.000 | 8.000 | 10.01 | | OK |
| | | | | | | Scale | Ratio | OK | | | |
| 9-7 | | H.W. | 77641 | 0 | 2.000 | 4.010 | 6.000 | 8.000 | 10.01 | | OK |
| | | | | | | Scale | Ratio | OK | | | |
| 10-4 | | E.A. | 77641 | 0 | 1.990 | 4.000 | 6.000 | 8.010 | 10.01 | | OK |
| | | | | | | Scale | Ratio | OK | | | |
| 11-5 | | E.A. | 77641 | 0 | 1.990 | 4.020 | 6.000 | 8.000 | 10.02 | | OK |
| | | | | | | Scale | Ratio | OK | | | |
| 12-5 | | H.K. | 77641 | 0 | 2.000 | 4.010 | 6.000 | 8.000 | 9.990 | | OK |
| | | | | | | Scale | Ratio | OK | | | |
| 1929 | | | | | | | | | | | |
| 1-8 | | H.K. | 77641 | 0 | 2.000 | 4.020 | 6.010 | 8.010 | 9.990 | | OK |
| | | | | | | Scale | Ratio | OK | | | |
| 2-4 | | H.K. | 77641 | 0 | 2.000 | 4.010 | 6.020 | 8.000 | 9.990 | | OK |
| | | | | | | Scale | Ratio | OK | | | |
| 3-4 | | H.K. | 77641 | 0 | 2.000 | 4.010 | 6.010 | 8.000 | 9.990 | | OK |
| | | | | | | Scale | Ratio | OK | | | |
| 4-2 | | H.K. | 77641 | 0 | 1.990 | 4.010 | 6.000 | 7.990 | 9.980 | | Pointer off zero |
| | | | | | | Scale | Ratio | OK | | | Pointer adjusted |
| 5-2 | | H.K. | 77641 | 0 | 1.990 | 4.010 | 6.000 | 7.990 | 9.980 | | OK |
| | | | | | | Scale | Ratio | OK | | | |

are tested for temperature coefficient, resistance, and conductivity. Upon the results of these tests depends the selection of the materials for manufacturing.

The Instrument Repair and Standardization Laboratory, therefore, occupies an important place in the manufacturing of electrical apparatus. It tests materials used in the construction of apparatus, and instruments and meters standardized in the laboratory are used in making all shop and field tests on completed apparatus.

## Fifteenth Anniversary

On June 14th the General Radio Company celebrated its fifteenth birthday. A brief history of this company appears in the June issue of their house organ "The General Radio Experimenter."

George W. W. Cornman, Treasurer and Manager of the Service Department of The Brown Instrument Company, retired from business August 8, 1930.

Mr. Cornman has been associated with the instrument business for 35 years, formerly being Secretary and Treasurer of the Keystone Electrical Instrument Company. When that organization was absorbed by The Brown Instrument Company, he became Treasurer and a Director of the present organization and was the active head of the Service Department, which was built up under his guidance.

The Service Department will be in charge of R. C. Kennan as Manager, and E. T. Nahill as Field Supervisor.

Mr. J. B. McMahon, the well-known Tulsa branch manager of The Foxboro Company, will hereafter make his headquarters at the home office at Foxboro. He is to take charge of all field engineering service and willl be responsible for all direct sales effort. Having a man of Mr. McMahon's experience in the field at the home office should be of distinct benefit to The Foxboro Company's many customers.

Mr. G. B. Lane, former manager of the Detroit office, has succeeded Mr. McMahon as branch manager at Tulsa. Mr. Lane is well equipped by experience and training to uphold the excellent reputation for service enjoyed by the Tulsa office.

The twenty-third annual meeting of the National Conference on Weights and Measures convened at the National Bureau of Standards of the Department of Commerce, Washington, on June 3 and remained in session for four days, during which a wide variety of subjects pertaining to the regulation of commercial weighing and measuring devices was discussed, and codes of specifications and tolerances affecting such devices were adopted and recommended for uniform promulgation by the States. State and local weights and measures officers were present from twenty-six States and the District of Columbia to the number of 109; the remainder of the total registration of 240 comprised representatives of the Federal Government, manufacturers of weighing and measuring equipment, railroad weighing departments, and distributors of products sold by weight or measure.

# Measurement of Air Flow

E. Ower, B.Sc. (Lond.), Hons.I., A.C.G.I.
*Bramwell Medallist; Member of the Institution of Heating and Ventilating Engineers; Assistant in the Aerodynamics Department, National Physical Laboratory*

## CHAPTER VI.

### THE PLATE ORIFICE, VENTURI TUBE, AND SHAPED NOZZLE.

The Pitot tube, in conjunction with a properly designed static tube, has the important advantage that its calibration has been definitely established by careful experiment, so that it can be, and, in fact, is, regarded as a fundamental standard for the measurement of wind speed. In the absence of any other standard of equal precision, it must play an important part in the calibration of all other instruments for air speed measurements. It is, however, subject to certain shortcomings for practical work. In the first place, as we have seen, it is not well suited to a rapid determination of quantity since the pipe section has to be traversed, and a certain amount of arithmetical work has to be performed. Secondly, the pressures to be observed are very often small so that sensitive manometers are required to give the necessary accuracy, and the design of such instruments to read accurately the velocity heads corresponding to air speeds of less than 1000 feet per minute, presents serious practical problems.

For these reasons methods have been sought in which the pressures to be measured are automatically augmented, and in which single readings enable the mean velocity in a pipe to be determined. Although such methods lack the certainty of the Pitot tube when used with a manometer of the requisite precision—as a general rule, in fact, it is safest to calibrate the apparatus employed by means of the Pitot tube if the highest accuracy is required—they are undeniably superior to this instrument as regards the ease and rapidity with which the necessary observations can be performed. Briefly, these methods consist in introducing into the stream some device such as a nozzle or an orifice plate which, at a given section of the pipe, constricts the free area through which the air can pass and so effects a local increase in velocity. It is then found that a comparatively large drop of static pressure is

experienced by the air in passing from the full diameter of the pipe to the section at which the constriction, and hence also the velocity, is a maximum, and that this pressure drop can be used as a measure of the air speed.

**Equations for the Flow through Orifices and Nozzles.**—Suppose that in a given pipe the walls are shaped as shown in Fig. 25, so that the area at section BB is less than at AA. Let $p_1$, $v_1$, $\rho_1$, $a_1$ be respectively the absolute static pressure (measured from zero), the mean velocity, the density of the air, and the area of the section at AA, and $p_2$, $v_2$, $\rho_2$, $a_2$ be the corresponding quantities at BB. Also imagine that the pipe walls at AA and BB and the directions of flow at these sections are parallel to the axis of the pipe.

We shall assume the flow to be frictionless, and at a later stage introduce numerical coefficients to cover the error involved

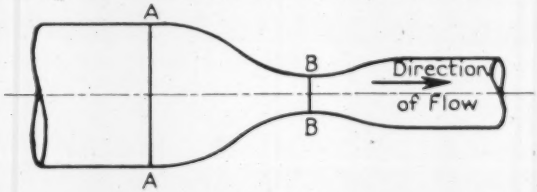


FIG. 25.

by this and other assumptions. Such coefficients will have to be determined experimentally.

The difference between the static pressures $p_1$ and $p_2$ will depend mainly on the ratio of $a_1$ to $a_2$. In many cases the ratio $\frac{p_1}{p_2}$ does not differ much from unity,* and in these circumstances $\rho_1$ and $\rho_2$, the densities of the air at the two sections, may be considered as effectively equal.

We start with the general equation derived in Chapter II.,

$$\frac{v^2}{2} + \int \frac{dp}{\rho} = \text{constant},$$

and apply it to the air between sections AA and BB. We then have

$$\frac{{v_2}^2 - {v_1}^2}{2} = \int_{p_2}^{p_1} \frac{dp}{\rho} \quad . \quad . \quad . \quad . \quad (1)$$

**Case (*a*) : $\frac{p_2}{p_1}$ Nearly Equal to Unity.**—In this case $\rho_2$

* It must be remembered that $p_1$ and $p_2$ are measured from zero, so that their mean value in most cases will be approximately atmospheric pressure or, say, 400 inches of water. Hence in such cases they may differ by about 8 inches of water—an easily measurable amount—before the ratio of one to the other differs from unity by more than 2 per cent.

may be taken as equal to $\rho_1$, which is equivalent to regarding the air as incompressible. Equation (1) becomes

$$\frac{v_2^2 - v_1^2}{2} = \frac{p_1 - p_2}{\rho} \quad . \quad . \quad . \quad . \quad (2)$$

Also, the weight of air flowing per unit time across AA is equal to that across BB, i.e.

$$\rho_1 a_1 v_1 = \rho_2 a_2 v_2,$$

or

$$v_1 = \frac{a_2 v_2}{a_1} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Substituting (3) in (2) we have

$$v_2^2 = \frac{2(p_1 - p_2)}{\rho\left(1 - \frac{a_2^2}{a_1^2}\right)}, \quad . \quad . \quad . \quad (3a)$$

and the weight of air flowing per second * is given by

$$q = g\rho a_2 v_2 = a_2 g \sqrt{\frac{2\rho(p_1 - p_2)}{1 - \frac{a_2^2}{a_1^2}}} \quad . \quad . \quad . \quad (4)$$

Actually, the flow will be less than this, the true value of $q$ bearing a ratio $\alpha$ to the theoretical value, $\alpha$ being less than unity; $\alpha$ is known as the coefficient of discharge and has to be determined, as stated above, by experiment. Inserting $\alpha$ in (4), and writing $r$ for the ratio of the upstream and downstream areas $\frac{a_1}{a_2}$, we have finally

$$q = \alpha a_2 g \sqrt{\frac{2\rho r^2(p_1 - p_2)}{r^2 - 1}}, \quad (5)$$

which is the equation for the flow of an incompressible fluid through an orifice or nozzle.

**Case** $(b)$ : $\frac{p_2}{p_1}$ **Appreciably Less than Unity.**—Compressibility can no longer be neglected, so that $\rho_2$ cannot now be taken as equal to $\rho_1$; the density will now change with $p$ according to the usual laws for gases. It is almost always the case in practice that the flow along the pipe is sufficiently rapid for the expansion ($p_2$ is less than $p_1$) in the nozzle or orifice to be taken as adiabatic, so that we have

$$\frac{p_1}{\rho_1^\gamma} = C = \frac{p_2}{\rho_2^\gamma}, \quad . \quad . \quad . \quad . \quad (6)$$

* It should be remembered that $\rho$ here has its customary significance of $\frac{\text{weight per unit volume}}{g}$ so that the weight of a volume V of air is $g\rho$ V units of weight.

where C is a constant and $\gamma$ is the usual index for adiabatic expansion (1·408 for dry air).

Hence in this case (1) becomes, since, from (6), $\frac{I}{\rho} = \left(\frac{C}{p}\right)^{\frac{1}{\gamma}}$,

$$\frac{v_2^2 - v_1^2}{2} = C^{\frac{1}{\gamma}} \int_{p_2}^{p_1} \frac{dp}{p^{\frac{1}{\gamma}}} = C^{\frac{1}{\gamma}} \frac{\gamma}{\gamma - 1} \left\{ p_1^{\frac{\gamma-1}{\gamma}} - p_2^{\frac{\gamma-1}{\gamma}} \right\}$$

and, if we put $C^{\frac{1}{\gamma}} = \frac{p_1^{\frac{1}{\gamma}}}{\rho_1}$, this reduces to

$$\frac{v_2^2 - v_1^2}{2} = \frac{\gamma}{\gamma - 1} \cdot \frac{p_1}{\rho_1} \left\{ 1 - \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} \right\} \quad . \quad . \quad (7)$$

The equation of continuity of flow, i.e. equal weights of air passing sections AA and BB in unit time, is, as before,

$$\rho_1 a_1 v_1 = \rho_2 a_2 v_2,$$

or, if the value for $\frac{\rho_2}{\rho_1}$ from (6) is inserted,

$$v_1 = \left(\frac{p_2}{p_1}\right)^{\frac{1}{\gamma}} \frac{a_2}{a_1} v_2.$$

Putting this value of $v_1$ in (7), and reducing, we have

$$v_2 = \sqrt{\frac{2 \cdot \frac{\gamma}{\gamma - 1} \cdot \frac{p_1}{\rho_1} \left\{ 1 - \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} \right\}}{1 - \frac{a_2^2}{a_1^2} \left(\frac{p_2}{p_1}\right)^{\frac{2}{\gamma}}}}, \quad . \quad . \quad (7a)$$

so that, inserting the discharge coefficient $\alpha$, and putting, as before, $r = \frac{a_1}{a_2}$, the weight of air flowing per second becomes

$$q = \alpha a_2 g \rho_2 v_2 = \alpha a_2 g \left(\frac{p_2}{p_1}\right)^{\frac{1}{\gamma}} \rho_1 v_2$$

$$= \alpha a_2 g \sqrt{\frac{2r^2 \cdot \frac{\gamma}{\gamma - 1} \cdot \rho_1 p_2^{\frac{2}{\gamma}} p_1^{\frac{\gamma-2}{\gamma}} \left\{ 1 - \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} \right\}}{r^2 - \left(\frac{p_2}{p_1}\right)^{\frac{2}{\gamma}}}}$$

$$= \alpha a_2 g \sqrt{\frac{2r^2 \frac{\gamma}{\gamma - 1} p_1 \rho_1 \left\{ 1 - \left(\frac{p_2}{p_1}\right)^{\frac{\gamma-1}{\gamma}} \right\} \left(\frac{p_2}{p_1}\right)^{\frac{2}{\gamma}}}{r^2 - \left(\frac{p_2}{p_1}\right)^{\frac{2}{\gamma}}}}. \quad . \quad (8)$$

This equation can be thrown into a form which is more convenient for practical purposes, since it involves the pressure drop $p_1 - p_2$ across the nozzle or orifice, which is easily measurable. Moreover, the modified form of the equation is more readily comparable with (5), the equation for the flow of an incompressible fluid.

Let us write R for the expansion ratio $\frac{p_2}{p_1}$ wherever it occurs in (8); then we may make the following substitution for $p_1$ where it occurs by itself $\left(\text{not as part of the ratio } \frac{p_2}{p_1}\right)$:—

$$p_1 = \frac{p_1}{(p_1 - p_2)} \times (p_1 - p_2) = (p_1 - p_2) \times \frac{1}{1 - R}.$$

Equation (8) may now be written thus:—

$$q = aa_2 g \sqrt{\frac{2\rho_1 r^2 (p_1 - p_2)}{r^2 - 1}} \times \sqrt{\frac{(r^2 - 1)\frac{\gamma}{\gamma - 1} \cdot \frac{1}{1 - R} \cdot (1 - R^{\frac{\gamma - 1}{\gamma}}) R^{\frac{2}{\gamma}}}{r^2 - R^{\frac{2}{\gamma}}}} \quad . \quad . \quad (9)$$

Comparing this equation with (5), we see that it is the equation for the discharge of air treated as an incompressible fluid, modified by the term under the second radical, which allows for the effect of compressibility. Equation (9) is the general equation for the flow of a fluid through a constriction. In practice the constriction in a pipe line consists of some device such as an orifice plate, a nozzle, or a Venturi tube, each of which is considered in detail in the sequel. When these appliances are suitably proportioned to the flow, a pressure difference ($p_1 - p_2$ in equation (9)) is set up of such a magnitude that it can easily be measured to the necessary degree of accuracy (within 1 per cent.) without a manometer of high sensitivity.

It will be seen that this pressure difference depends upon the ratio of the diameter of the pipe to that of the minimum section presented by the constriction, an increase in this ratio producing a corresponding increase in the pressure difference to be measured. Practical limitations may of course prevent the minimum section from being too small in relation to the pipe, but even so the pressure difference can be made much larger than the velocity head in the open pipe. As an example of the advantage to be derived from this feature of a constriction we may take the case of a 6-inch diameter pipe in which the

mean velocity is 20 feet per second. The corresponding velocity head is about 0·09 inch of water, whereas if a 3-inch diameter plate orifice be inserted in the pipe, the pressure drop across it will be about 3·7 inches of water, i.e. about 40 times the velocity head.

A further merit of the method of measuring the flow in a pipe by means of a constriction lies in the fact that, since no traverse of the pipe is necessary, as in the case of Pitot tube measurements, it lends itself readily to the taking of continuous records of the quantity of air flowing. For this purpose it is merely necessary to transmit the upstream and downstream pressures to a recording differential pressure gauge, the charts for which may be graduated to read in inches of water, or, if great accuracy is not of importance, directly in pounds of air per minute. In the latter case, of course, the corrections for compressibility and the variations of density of the air with temperature and pressure have to be neglected, and, in order to reduce errors as far as possible, it is advisable to adjust the gauge to read correctly at the estimated mean conditions of temperature, pressure, and pressure drop across the orifice to which it is likely to be subjected when in use.

The chief difficulty in the practical application of this method of measurement arises in assigning a value to $\alpha$, the coefficient of discharge. A large amount of experimental work has been done, particularly with the thin plate orifice, to establish values of $\alpha$ for the various forms of constricting devices, but many of the experimenters do not seem to have been fully acquainted with the various factors which affect the value of the coefficient, and their work has in consequence lost some of its value, as no general conclusions can be drawn therefrom.

Before we discuss practical cases in detail it will be instructive to consider the question of the coefficient of a constriction from a general point of view. In a device such as a properly designed Venturi tube or a shaped nozzle in which the stream at efflux is parallel, the coefficient approaches the value unity, so that the actual discharge is only slightly less than the theoretical. The slight reduction that does occur is mainly attributable to the frictional loss in the passage of the fluid through the constriction. In the case of an orifice cut in a thin plate inserted in the stream, the actual discharge is considerably less than that calculated by the use of equation (9), taking $a_2$ as the area of the orifice. This is due to the fact that the stream issues from the orifice not in the form of a parallel jet, but as a convergent jet, the section of minimum area, which is of the order of 0·6 or 0·7 times the area of the orifice, occurring at a distance of somewhat less than a pipe diameter or so from the plane of the orifice. The section of

minimum area is known as the *vena contracta*; after passing this section the jet commences to expand, and the pipe will again run full some few diameters downstream from the orifice. Further reference to orifice coefficients will be found below.

**Variables Affecting the Discharge Coefficient.**—Let us now consider the variables that affect the coefficient of discharge of a constricting device in the general case of the flow of a compressible fluid. These variables will be found to be :—

(*a*) the density of the fluid } at the section of minimum
(*b*) the viscosity of the fluid } area of the constriction ;
(*c*) a speed characteristic of the flow ;
(*d*) a linear dimension characteristic of the size and shape of the constriction ;
(*e*) a property of the fluid characteristic of its compressibility ;
(*f*) the ratio of the diameter of the constriction to that of the pipe.

For (*c*) we may take $v_2$, the mean speed of the fluid through the throat, or section of minimum area of the constriction, and for (*d*) the diameter $d_2$ of the throat. For the compressibility it is customary to take the ratio $\frac{v_2}{V}$ where V is the speed of sound in the fluid. This ratio, which can be shown to be characteristic of the compressibility, can be reduced to the form $\sqrt{\frac{\rho_2 {v_2}^2}{\gamma p_2}}$. By making use of the relation between $v_1$ and $v_2$, and between $\frac{p_1}{{\rho_1}^\gamma}$ and $\frac{p_2}{{\rho_2}^\gamma}$, we can transform the expression $\sqrt{\frac{\rho_2 {v_2}^2}{\gamma p_2}}$ to

$$\sqrt{\frac{2\left\{\left(\frac{p_2}{p_1}\right)^{\frac{1-\gamma}{\gamma}} - 1\right\}}{(\gamma - 1)\left\{1 - \frac{{a_2}^2}{{a_1}^2}\left(\frac{p_2}{p_1}\right)^{\frac{2}{\gamma}}\right\}}}$$

The important point to notice is that this expression is a function of the expansion ratio $\frac{p_2}{p_1}$ and may be denoted by $(\beta)\frac{p_2}{p_1}$.

The variables mentioned above may be collected into three groups, each of which may be regarded as a single variable upon which the value of $\alpha$ in part depends. These new variables will be found to be $\frac{v_2 d_2 \rho_2}{\mu_2}$, $(\beta)\frac{p_2}{p_1}$, and $\frac{d_2}{d_1}$, the first of which,

when $\nu$ is substituted for $\frac{\mu}{\rho}$, becomes $\frac{v_2 d_2}{\nu_2}$; $\alpha$ may therefore be represented by the equation,

$$\alpha = f\left(\frac{v_2 d_2}{\nu_2}, (\beta)\frac{p_2}{p_1}, \frac{d_2}{d_1}\right) \quad . \quad . \quad . \quad (10)$$

where $f$ is some function of the three variables concerned

This is an important equation which merits careful study, and we may profitably consider its practical significance. If we have two geometrically similar * constrictions of different sizes, the ratio $\frac{d_2}{d_1}$ for each will be the same. If, further, we arrange the conditions of flow so that $(\beta)\frac{p_2}{p_1}$ and $\frac{v_2 d_2}{\nu_2}$ are the same for the two constrictions, equation (10) indicates that the coefficients of discharge for the two constrictions will be equal, despite the fact that the latter are of different sizes and that the individual values of $p_1$, $p_2$, $v_2$, etc., may not be the same in the two cases. If any one of the quantities in equation (10) alters in such a manner as to change the value of the ratio in which it occurs, the coefficient $\alpha$ is liable to change.

In the case of the flow of an incompressible fluid, the term $(\beta)\frac{p_2}{p_1}$ ceases to have an influence on the type of flow through the constriction, and hence, on the value of $\alpha$. Further, for a series of geometrically similar constrictions, $\frac{d_2}{d_1}$ will have the same value, and the value of $\alpha$ for this series can be changed only by a change in the value of $\frac{v_2 d_2}{\nu_2}$. Hence for the flow of an incompressible fluid through any one of a series of geometrically similar constrictions, equation (10) reduces to

$$\alpha = f\left(\frac{v_2 d_2}{\nu_2}\right), \quad . \quad . \quad . \quad (11)$$

where the form of the function $f$ is now the same for all members of the series, but will vary from one series to another, and $\nu$ may be measured anywhere in the pipe, since it does not vary with pressure.

From (11) it is apparent that if any one of the quantities in the ratio $\frac{v_2 d_2}{\nu_2}$ is altered, the value of $\alpha$ will not change if one or both the other quantities are correspondingly altered by

* Two bodies, A and B, are geometrically similar when all linear dimensions of A bear a constant ratio to the corresponding dimensions of B.

amounts such that the ratio remains constant. Thus, suppose for a given form of constriction a value of $\alpha$ is obtained for water flowing at a mean speed $v_2$ through the section of minimum area. The value of $\nu$ for air is about 13 times that of water, so that the given constriction will have the same value of $\alpha$ with air, if the speed is increased thirteen-fold. Alternatively, a geometrically similar constriction, having a throat diameter thirteen times that of the original, will have a value of $\alpha$ for air equal to that of the original for water, the throat speeds in the two cases being the same.*

Although equations (10) and (11) do not provide a means of obtaining actual numerical values of $\alpha$, they are of value in that they indicate the manner in which this coefficient will vary under different conditions. They therefore furnish a basis upon which the work of various experimenters can be correlated so that their results can be given the widest possible application.

We turn now to a consideration of the various practical methods employed to introduce a constriction in a pipe line in order to measure the flow from the pressure drop set up.

**The Plate Orifice.**—Mechanically, the plate orifice is the simplest of the devices under consideration in this chapter, and is, moreover, the one most easily inserted into an existing pipe line with a minimum of alteration to the lay-out. Unfortunately, however, it is the device in regard to whose discharge coefficient the most uncertainty exists. As usually employed it consists simply of a thin plate or diaphragm, clamped between two flanges of the pipe, and having a circular hole, coaxial with the pipe, cut in it, as in Fig. 26. Two pressure taps, one upstream and one downstream of the plane of the plate, serve as a means of measuring the static pressure drop $(p_1 - p_2)$ from which the delivery is calculated according to equation (9).

Equation (9) can be thrown into a form which is more convenient for practical use. As it stands it will give the quantity of air flowing in pounds per second, the area $a_2$ being measured in square feet, $\rho_1$ in slugs per cubic foot, and $p_1$ and $p_2$ in pounds per square foot. In practice it is usually more convenient to derive the quantity $Q$ in pounds per minute, and to measure the area $a_2$ of the orifice in square inches, and the pressure difference $p_1 - p_2$ in inches of water. It will also be convenient to insert the value for $\rho$ under standard conditions of temperature and pressure (0·00237 at 29·92 inches of mercury and at 60° F.), and to apply a correction for the conditions prevailing at the time of the observations. The pro-

* In this illustration it is assumed that $\frac{p_2}{p_1}$ is nearly unity, so that the air can be regarded as incompressible.

cedure in modifying equation (9) is similar to that performed in detail in equations (3), (4), and (5) of Chapter V., and need not be repeated here. The final form of the modified equation as recommended for practical use will be found to be, if we write C for the compressibility factor represented by the second radical term in equation (9),

$$Q = 8{\cdot}78 a a_2 \sqrt{\frac{r^2}{r^2 - 1} \cdot (h_1 - h_2) \frac{b}{(460 + t)}} \times C$$

pounds per minute, . . . . (12)

where $a_2$, as stated above, is the area of the orifice in square inches, $(h_1 - h_2)$ is the pressure drop across the orifice in

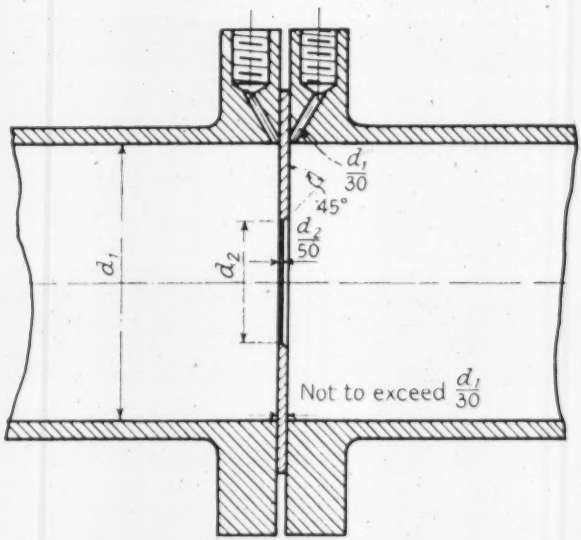


FIG. 20.—Hodgson's sharp-edged orifice.

inches of water, $t$ is the temperature of the air in the throat of the orifice in degrees Fahrenheit, and $b$ is the barometric height in inches of mercury. If $h_1$, the static pressure head in the pipe upstream of the orifice, is more than 8 inches of water above or below atmospheric pressure, $b$ must be increased or diminished by the equivalent of $h_1$ in inches of mercury, according to the note.*

We have now to consider the value of the discharge coefficient $a$, and the magnitude of the compressibility factor C. As we have already observed, the stream immediately on leaving the orifice is convergent, and reaches a minimum

* Note that $\sqrt{h_m}$ is obtained directly from § 2 of this summary.

area, appreciably less than that of the orifice, some distance downstream of the orifice. It is not until this section is reached that the flow is parallel to the axis of the orifice. Now the equations hitherto derived for flow through constrictions are based upon the assumption that the flow is parallel at the sections of maximum and minimum area. Strictly, therefore, in applying these equations to orifice flow, the area $a_2$, wherever it occurs, should be taken as the area of the vena contracta, and not as that of the orifice itself. Similarly, the downstream pressure $p_2$ should be the static pressure at the vena contracta.

Obviously, the area of the vena contracta cannot be measured accurately in practice, nor can its exact position be easily determined; it is therefore usual to take $a_2$ as the area of the orifice, and to make the experimentally determined discharge coefficient suit this condition. It is because $a_2$ is appreciably greater than the area of the vena contracta that the discharge coefficient is so much less than unity. Approximate measurements of the vena contracta have been obtained from experiments made with orifice plates in glass tubes along which water was flowing. It is interesting to note that when this area was substituted for $a_2$ in equation (5), the value of $\alpha$ was found to be very much nearer unity, and of the same order as that for a Venturi tube or shaped nozzle, in which the minimum section corresponds with the actual minimum area through which flow takes place. The pressure at the vena contracta is found to be less, but not much less, than that close to the downstream side of the orifice, whilst on the upstream side the pressure rises somewhat in the immediate vicinity of the orifice plate.

America's first Institute of Applied Optics is to be launched at the new University of Rochester in September. A new building given by the families of John J. Bausch and Capt. Henry Lomb and dedicated to the memory of those pioneers of American optics, was formally presented to the new University on July 25, on the occasion of the hundredth anniversary of the birth of J. J. Bausch.

A memorial plaque in the new building was unveiled and Carl F. Lomb, on behalf of these two families represented, dedicated it in memory of J. J. Bausch and Henry Lomb.

Organization of the Institute provides for a finance committee consisting of Raylond L. Thompson, treasurer of the University; J. F. Taylor of the Bausch & Lomb Optical Company, and F. M. Page of the Eastman Kodak Company. There is also an administrative committee consisting of President Rush Rhees, Dr. T. Russell Wilkins, acting director of the Institute; Lloyd Jones of the Kodak Company, and W. B. Rayton of Bausch & Lomb Company.

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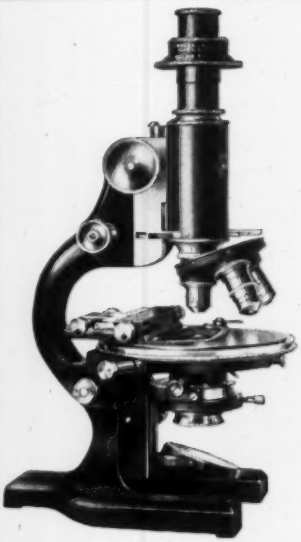

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## CHAPTER VI. MEASUREMENTS OF LENGTH

(Continued)

### 3. Measuring Screws and Their Practical Application

Just as important as the application of the vernier for measuring purposes is the development of screws for the same purpose. One may consider that a screw-thread which is guided in a stationary nut can be moved in its axial direction very accurately within very small lengths. Let us assume we have a thread with a pitch of 1 mm, i. e. if the screw is turned one complete revolution, we have moved it 1 mm. Or, if we keep the screw immovable by a special arrangement in its axis or have the nut arranged so that it can move along the screw without rotating, the nut is moved 1 mm by one rotation of the screw. If we have now provided at the head of the screw a division we can read fractions of a rotation of the screw. For example, if the head of the screw has a diameter of a little more than 30 mm it has a circumference of 100 mm and we can arrange without difficulty 100 divisions on its circumference, and it is quite obvious if we have a fixed reading mark, that a rotation of the screw of one division corresponds exactly to an axial movement of the screw or nut of 0.01 mm. In such cases we can make or measure without difficulty displacements of 0.001 mm, i. e. make measurements with a screw of 1 mm pitch of about 1/1000 of that value, and as there is no difficulty whatever in precision machining to make screws for measuring purposes with threads of as small a pitch as 0.3 mm, screws can therefore be used for measurements down to a few ten thousandths of millimeter. It offers no difficulty to make the head of the screw as large as conditions require.

Before this is discussed in more detail something may still be said about the possible errors of such screws although in general they will be of no importance to the chemist. It is evident that by moving a screw through its nut a certain play, usually filled with oil must be there in order to have free movement: and then that no thread can be made absolutely exact. The principal errors which can occur in measurements with a screw are two-fold: the progressive error and the periodic error. The former means that the pitch of a thread will not be quite uniform over its whole length but will vary slightly from thread to thread. This can, of course, amount to only very little as otherwise the screw would not be able to pass through the nut. These are usually errors which are caused by the screw or the thread-cutter getting hot during threading, or that the screw is deformed slightly during manufacture due to temperature changes which might be quite considerable. The other error is characterized by the fact that it is almost the same for each thread; if the thread of a screw is evolved in one plane by rolling it over the latter always parallel to itself and it records how the single pitch runs, this line for an ideal screw must be an abso-

lutely straight line. Practically, however, it will be represented by a curve if an appropriate magnification is employed. The deviations of this curve from the straight line represents the progressive errors of the screw and periodical variations of the curve in equal distances the periodic errors. The latter are generally caused due to the tool cutting the thread not being uniformly moved during one revolution of the screw, an occurrence which repeats itself in exactly the same manner for each revolution. Both errors which for finest measurements must be determined and taken into consideration are, by the way, so small in modern screws that they can almost always be neglected.

It is different with an error which is due less to the screw but to its support, and which is called play. As said before, a screw has to be guided in its nut with a certain clearance so that it can pass without binding. To facilitate this motion and to save the thread the screw is oiled and so the interstices are filled with oil. In moving the screw, by pushing or pulling when turning, one or the other side of the thread of the screw will touch the grooves in the nut. The screw can therefore move slightly in the direction of its axis by using a slight pressure, and this may cause serious errors. These errors are designated as "play." As far as is possible constructively, care is taken by inserting springs or similar means so that a screw is always pressed only in one definite direction against the nut so that this play is eliminated as much as possible. It should, however, be made a rule to always adjust all measuring screws only in such manner that the screw is always turned in one direction, i. e. in the direction of increasing numbers on the drum. If the screw has been turned too far one should go back a full turn and adjust anew.

A few of the practical applications of the measuring screw will be discussed below. At first the well-known, well-developed form of the screw-micrometer (Fig. 23), a little instrument which is used industrially in several types for measuring thicknesses of many kinds. The usual industrial type is made almost always with 0.5 mm pitch thread, which runs in a nut C which, in its turn is placed in a U-shaped frame. The head of this screw is usually shaped as a sleeve (D) so that it surrounds a cylinder C in which the real nut C, is placed. This cylinder has a division of half millimeters for counting the full revolutions of the screw while on the sleeve itself a division of 50 parts is generally provided so that each division is equal to 0.01 mm. On the opposite leg of the U-frame is a fixed counter-point A. The body to be measured is placed between this and the end of the screw. Both measuring faces of the micrometer are carefully ground plane and parallel. For a measurement, the screw is turned so far that the body to be measured just touches both faces, its thickness can then be read directly on the division, however only under the assumption that when the screw touches point A the reading shows exactly zero. If the micrometer does not give this reading, the reading at this point must then either be subtracted from or added to the reading of the screw ,or point A must be adjusted which can be effected by a small screw provided for this purpose.

More recent micrometer-screws of this type of specially good quality are able to make measurements accurate to 0.003 mm. With such a guarantee by the manufacturer, it must be considered that a measurement can be falsified considerably if the screw is turned so hard that the U-frame, even though it be very rigid, is sprung slightly. To prevent such errors,

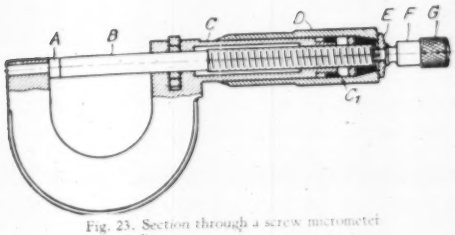



Fig. 23. Section through a screw micrometer

Fig. 26. Diagram of a test indicator.

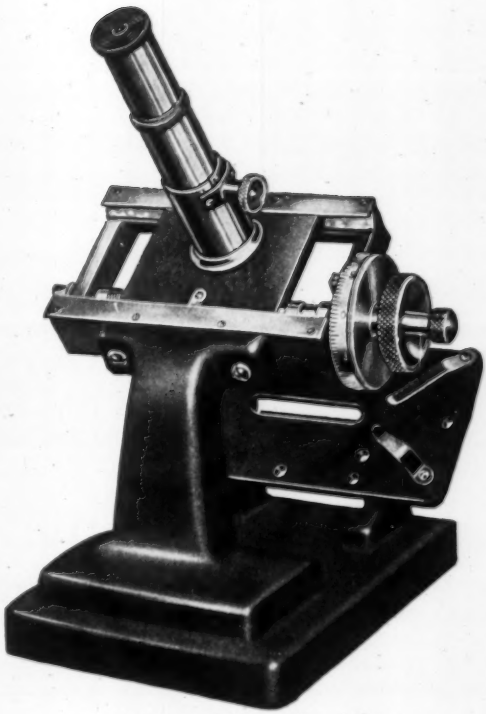


Fig. 24. Comparator (*Gaertner Scientific Corp.*)

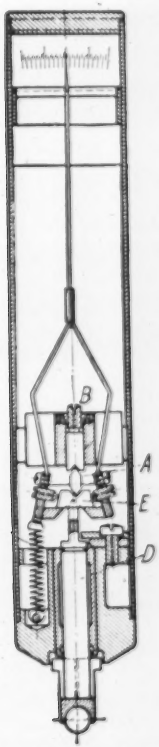



Fig. 27. Section through the Horth Minimeter. (B rigid support, A rigid knife edge, E rotating piece with pointer, D contact piece with second knife edge.)

high grade micrometers are provided, without exception, at the head of the screw with a so-called friction-coupling E, an arrangement which only permits the screw to be turned with a certain force. If, therefore, one attempts to turn harder than necessary, that is if the screw offers a certain resistance to turning because it already presses sufficiently hard against the counter-point, only the coupling-head is turned without the screw moving any further. In other words, the measurement is always carried out with the same contact pressure. An error due to the play is hereby practically eliminated. Such micrometer-screws are manufactured in all sizes from the smallest to the largest dimensions and with the most varied shapes of holder, also for permanent installation, however almost without exception for a range of 25 mm; larger micrometers also have only this range, i. e. from 25 to 50 mm, from 50 to 75 mm, etc. These latter types can, therefore, not be closed entirely, there is consequently no checking of the zero point. For this purpose the manufacturers regularly supply so-called measuring discs the diameters of which are adjusted to the smallest value. If such a disc gives the value marked on it when measured with the micrometer, it is a proof that the latter is correct. A deviation from the normal value of the disc must then be eliminated by adjustment or corrected correspondingly.

Mention may also be made of an arrangement of a measuring screw which frequently finds use for microscopic measurements, namely the so-called objective micrometer. It consists of a plate which is arranged on the object-table of a usual microscope and carried in a bearing as a micrometer-screw of suitable form and pitch which is arranged for measuring purposes. A small slide is connected with this micrometer-screw on which objects can be placed which are observed through the microscope. By moving the screw these objects can be displaced laterally by exactly measurable amounts. By observing these displacements the microscope measurements of lengths can be made with considerable accuracy.

Much more frequently the measurement is carried out in somewhat different manner, namely by making the microscope itself movable by means of a measuring screw. Such a device is called a comparator, often also a measuring microscope (Fig. 24). Herewith a suitable measuring screw usually of larger form with 1 mm pitch is arranged stationary and provided on one side with the usual division head. The nut is secured against rotation by a guide and on the nut is fastened a microscope with suitable magnification (generally for the usual necessary measurements about 20 to 100 times) which has ocular cross-hairs. When turning the measuring screw the microscope is displaced by amounts which can be read on the screw. If, therefore, objects, scales, etc. are placed under the objective their length can be measured by adjusting the microscope by means of the measuring drum to the limiting lines, faces or marks. Devices of this kind are useful for many purposes, very frequently they are used for evaluating photographic plates in larger forms where the plate is supported sufficiently rigidly and the microscope can be adjusted on each point of the plate; this method is especially preferred for astronomical measurements for evaluations of stellar photographs. The apparatus is also often built in such a way that the microscope can be moved in two directions at right angles to each other which is often desirable for the evaluation of curves. But hereby one often proceeds differently by using the above described objective-micrometer, for instance so that in the one direction the microscope itself is moved by a measuring screw while in the other direction the

table with the photographic plate is made movable. Naturally, there exist the most varied possibilities.

As a last extremely important arrangement may finally be mentioned the so-called ocular-micrometer which, also, is very frequently used. Very often, it is also called a micrometer-microscope (Fig. 25). In principle, it can be described as follows: A microscope is directed on the small object to be measured, of which the objective gives a magnified image in the plane of vision. This image is seen, again magnified, through the eye piece. In

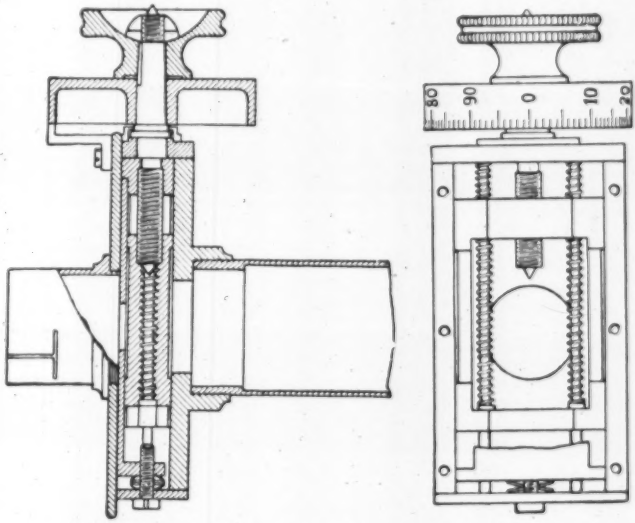



Fig. 25. Section through a micrometer microscope.

the field of view of the objective a mark is made which is seen simultaneously with the object through the eye piece. This mark in the plane of vision is moved in this plane by a small measuring screw. This screw is turned by a divided drum which is arranged at the side of the ocular. The screw moves a little frame in the plane of vision, the frame is very exactly guided by the motion of the screw in its nut, and in the interior of the frame the image of the object appears. A few fine hairs are stretched across the face of the frame which make possible the adjustment to the object. This arrangement is particularly in favor for exact reading of divisions. In this case, the adjusting marks consist almost always of two fine parallel hairs which are such distance from each other that apparently the image of the line of the scale to which it is adjusted just fits between them. If measurements are to be made with such a device the following must be observed: the pitch of the micrometer screw is hereby entirely unknown, the screw is also almost entirely inaccessible. The real pitch is practically immaterial because the object to be measured already appears magnified by the unknown magnification of the objective in the plane of the measuring screw. It is wholly immaterial what distance corresponds to one revolution of the screw in the plane of vision, but one wants to know the length corresponding to one revolution of the screw taking into consideration the magnification of the objective. Take for example, the case of an objective with a magnification of exactly ten times and a measuring screw of 0.5 mm pitch,

then one revolution of the screw corresponds to 0.5 mm, and from this it results that an object of only 0.05 mm length can just be measured by one revolution of the measuring screw. As magnification and pitch are not known the value of one rotation of the screw must be determined in every individual case by means of a scale. This holds true especially if such a microscope has interchangeable objectives or the length of the tube can be changed as then, of course, also a change of magnification of the objective occurs. A change of magnification of the ocular is naturally of no consequence. This is the general case. Generally these microscopes are manufactured so that they have fixed objectives and fixed lengths of tube so that these can not be changed. And further, the whole system is usually adjusted, so that a quite definite value of length corresponds to one revolution of the screw. Usually one revolution is equal to 0.1 mm, that is if the microscope is directed on a scale which is divided in 0.1 mm, the cross hairs in the field of vision are just moved one division if the screw makes one revolution. If the drum is divided into 100 parts, one division is then equal to 0.001 mm, i. e. with such a microscope, measurements can be made with an accuracy of a few ten thousands of a millimeter. Due to the great accuracy great care must, however, be taken to eliminate errors due to play as described above.

All devices described in the foregoing which, without exception, are also used for making finer measurements of length, accomplish this by either, as for instance in the microscopes, magnifying the length to be measured and then evaluating the magnified length, or, as in the screw micrometer, by making visible small movements by magnification, that is indicating small movements of the screw in the direction of its axis by means of a divided drum whereby a movement of a length of about 0.5 mm, corresponding to the pitch of the screw, is magnified to a length of about 30 mm on the circumference of the division drum. This is, after all, the principle of quite a number of measuring devices for measuring small lengths or small differences of length, namely the proper magnification of a length or of a difference of lengths respectively.

### 4. Test Indicators, Dial Gages

In all cases in which a very short length must be measured, perhaps fractions of a millimeter only or, what is the same, small differences of length of two pieces of which the one has a known length, certain devices can be employed as already mentioned, which are called test indicators. They serve, without exception, to magnify small changes of length or differences of length and thereby to make them more easily visible and also measurable (Fig. 26). Both do not necessarily have to be the same as a magnification will not always take place uniformly. In principle, for instance, the measuring screw is also a dial gage as it magnifies the motion of the screw in its axis into the rotation of the division drum. In a certain sense also the micrometer microscope operates in this manner though it can not be termed a mechanical dial gage.

First we have the so-called dial indicator. A movable pin, transmits its movement in its axis to a gear of such ratio that a displacement of 1 mm corresponds to a rotation of the pointer of one full revolution. This pointer passes over a dial like the hand of a watch, and each revolution corresponds to 1 mm so that if the dial is divided into 100 parts a few thousandths can easily be read. The range of such a dial indicator is a few millimeters.

A great number of other constructions of test indicators use simple levers whereby the ratios of the levers are made very large, 1 to 10 up to 1 to 100. It must be noted that by connecting such levers in series, the ratios of the levers must be multiplied, that is, if one has two levers the arms of which have a ratio of 1:50, and if the short arm of the one is moved a little then the end of the long arm passes through a fifty-fold distance and if this again acts on the short arm of the second lever the end of the long arm covers a 2500 times longer distance. Details of all these constructions will not be discussed. Only one frequently employed construction will be considered, the so-called Hirth-Mimimeter (Fig. 27) which uses only one lever arm which is supported like a balance on a center knife-edge and where another knife presses on the one end of the lever at a distance of only a few fractions of a millimeter from the center knife-edge. The free lever arm lengthened to about 10 cm. serves as the pointer so that magnifications up to a thousand times can be obtained within however, a very small range.

## 5. Special Measuring Apparatus

In the following, a few special constructions of higher-grade measuring instruments will be briefly considered.

First, a general remark on all those measuring devices, which are provided with measuring-microscopes and micrometers, may be made. When adjusting such microscopes the following is of very special importance. It is a condition for the good operation and correct measurement with such microscopes that the image of the object falls into the plane in which the adjusting threads of the micrometer are located. As long as this is not the case an accurate measurement is not possible. To obtain this condition one must proceed as follows: at first the microscope is directed against a brightly illuminated surface so that the field of vision is uniformly illuminated for example against the sky; then the ocular is adjusted until the cross-hairs are clearly defined. This must be done very carefully in order not to put unnecessary strain on the eye, in other words: the adjustment of the eye when looking at the cross-hairs should be exactly the same as when looking at distant objects. For this reason, the adjustment against the sky is the most advantageous. This position of the ocular is not changed, and then the whole microscope is adjusted to the object by changing its distance from it. This adjustment is completed only when the object appears perfectly sharp, as distinct as the cross-hairs. This can be recognized very simply by the phenomenon that the object apparently does not move with respect to the threads if the eye is moved a little to or away from the ocular. If by moving the eye, objects and cross-hairs remain perfectly stationary with respect to each other, the plane of vision and plane of cross-hairs coincide exactly. Then only is the adjustment of the microscope completed, and one achieves simultaneously that, if another observer with other vision wants to work with the microscope he has only to change the position of the ocular to full sharpness of vision without changing the adjustment of the microscope. The careful observance of this rule for all microscopic measurements can not be emphasized sufficiently.

An instrument which is frequently used in chemical laboratories due to its flexibility is the thickness indicator (Fig. 28). It consists essentially of a measuring rod which is suspended with a counter-weight so that it can be moved in the vertical plane and rested on the object with only slight pressure. Its upper end carries a measuring scale against which one

of the usual micrometer-microscopes is directed. This scale is usually divided into 0.1 mm. In its extension downward the rod has a contact ball where other contact pieces can also be attached. The stand carries at the bottom a well planed plate, the plane of which is exactly at right angles to the axis of the rod and on which the object to be measured is placed. For the measurement, the rod is lowered to the plate then the zero line of the scale appears in the field of view of the microscope. The micrometer is adjusted to this line and a reading made. After this, the rod is raised, the object to be measured placed on the plate and the rod again lowered until the contact point touches the object. Care must be taken that the object is placed so that, for circular objects, the actual diameter is measured, in a cylinder the largest diameter, the same for a sphere, or, for the tube of polarisation apparatus for determining sugar the real length of the axis of the tube and not a length from the center of the front surface at the bottom to a point at the side of the center of the upper surface, which of course, would give a value, which is too large. In the field of view of the microscope another line will appear at the place where the threads are, or, what is the same, the adjustment threads will lie apparently between two lines, and so the length can at first be approximately determined to 0.1 mm and then the distance between threads and next line must still be evaluated with the micrometer. The microscope is arranged in such manner that one revolution of the drum is equal to 0.1 mm so that the conversion of the differences of adjustment into millimeters is easily made, and the numbering is chosen so that the direction of this correction becomes clear directly. The actual length of the object can therefore be immediately determined from the differences of the two readings of the drum to a few ten thousandths of a millimeter. One must only take into consideration that the image is reversed in the plane of the threads of the microscope.

Another apparatus, which is of importance to the chemist for precise length measurements and especially for measurements of pressure, is the cathetometer. It is a special device for measuring length in vertical direction. Its types of construction are different, two principal forms can be distinguished. In each case, a vertical column is provided along which one or two microscopes or telescopes can be moved. (Whether these are microscopes or telescopes is immaterial for use as they are only built differently in order to be able to adjust to suitable distances since cathetometers are used for measuring with very short object distances of perhaps a few centimeters up to longer ones of about a few decimeters to one meter and more.) The microscopes also can be moved along this vertical column. Their optical axes are perpendicular to the column which is ascertained by special devices. Two possibilities exist; either, only one microscope is used and a scale is attached to the column, and the position of the microscope is transmitted to the scale in some way. With moderate accuracy by means of a vernier attached to the carrier of the microscope and gliding over the scale, or, for greater accuracy, by means of a micrometer-microscope also attached to the microscope carrier. If, for instance, the height of a mercury column in a barometer is to be measured the sighting microscope is adjusted to the lower meniscus of the mercury and the position on the column is read with the vernier or micrometer microscope; then the whole is shifted to the level of the upper menscus of the mercury, adjusted again, and the scale is read and in this way the exact height of the mercury column is obtained.

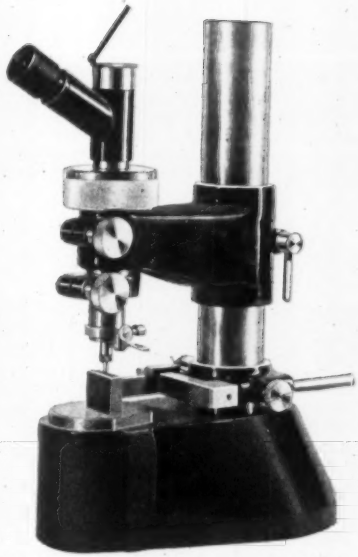


Fig. 28. Thickness Indicator. (Bausch & Lomb Optical Company).

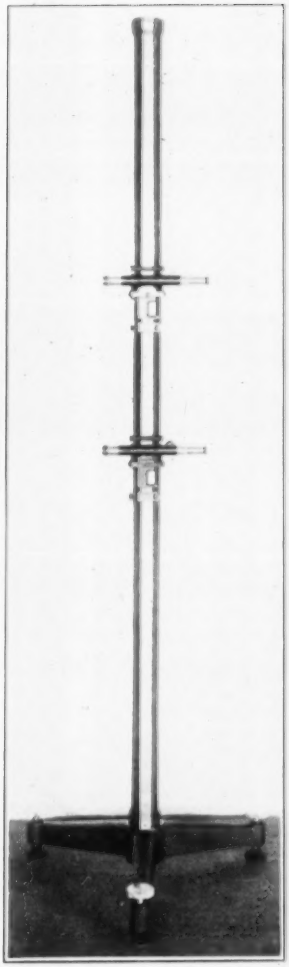


Fig. 29 (right). Cathetometer. (Gaertner Scientific Corp.).

The other method attaches the scale not to the column but places it separately alongside the length to be measured. Here two microscopes are most advantageously used with the cathetometer. They both are sighted on the ends of the length to be measured, and after this has been done the cathetometer is turned round so that the scale appears in the field of vision. Then one adjusts to the scale and the exact length is read. In simpler constructions, this is also done by the use of only one microscope by first making the measurement at the lower end and then at the upper (Fig. 29).

When carrying out a measurement of this kind several precautions have to be taken. First it must be ascertained how the length to be measured is situated, whether in fact an exactly vertical distance is measured whereby it is, of course, not necessary, as is the case in a mercury barometer, that

both menisci are located exactly vertically above each other. Only the distance of the two horizontal planes of these two menisci is of interest a fact which, however, sometimes makes the measurement somewhat more difficult. Further, the scale must under all conditions, be placed vertical as it is quite obvious that an inclination of the scale apparently changes its length as a simple calculation shows. A scale of the length $l$ which is exactly at right angles to the axis of the microscope has, at a deviation of the angle of this direction the apparent length $l \cos\alpha$. Its shortening therefore amounts to $l\,(1\text{-}\cos\alpha)$. In the following the values for this are tabulated.

| $\alpha =$ | $1\text{-}\cos\alpha$ | Apparent shortening for 1 m length in mm |
|---|---|---|
| 1° | 0.00015 | 0.15 |
| 2° | 61 | 0.61 |
| 3° | ·137 | 1.37 |
| 4° | 244 | 2.44 |
| 5° | 381 | 3.81 |
| 10° | 01519 | 15.19 |

The same, of course, holds true if the scale is placed into the cathetometer. A satisfactory measurement would, in this case, only be obtained if scale and length to be measured lie exactly parallel which, however, cannot be recommended. And finally, care must be taken that both optical axes of the microscopes must be exactly horizontal. In this respect one must consider: if in adjusting the microscopes these are sighted on the two ends of the length to be measured while the axes of the microscopes are parallel that does not mean that these axes remain parallel if the column of the cathetometer is turned for adjusting to the scale.

Practically, one therefore proceeds by correctly adjusting the cathetometer. In the first place this requires that the column be exactly vertical. To be able to carry out this adjustment every cathetometer is provided with three adjusting screws and the necessary number of levels. If a column is to stand exactly vertical it must be in the intersection of two planes which themselves are vertical.

This vertical adjustment of the column must be made as carefully as possible, it can, however, never be perfect as naturally the column is never a perfect straight line. In all cases, therefore, the adjustment of the microscopes is of importance. If one microscope is used for alternate adjustment at the lower and upper end, and if the cathetometer itself carries the scale, the transmission of the length to be measured to the scale is correct only if the microscope in both positions is exactly horizontal and thus parallel to itself. A simple calculation as before shows what must be required in this respect. For this reason, also the microscopes are provided with levels making an exact horizontal position possible. It is not absolutely necessary that the optical axes of the microscopes are exactly horizontal, it is only necessary that they are parallel in both positions. If the scale is placed beside the object to be measured the same rules hold. It must also be taken into account that the inclination of the microscope axes can change when the column is turned. There are, therefore, quite a few precautions to be observed if accurate measurements must be obtained, especially if the distance between cathetometer and distance to be measured is comparatively large. If two microscopes are used for adjustment and a separate scale is employed then the principal condition is that the axes of both microscopes remain in the same horizontal in both adjustments.

# The Engineer's Handbook of Industrial Instruments

M. F. Béhar*

## CHAPTER II
## Industrial Temperature Instruments

### Part 5—AUTOMATIC TEMPERATURE CONTROL

*(Concluded)*

### 8. Valve and Damper Apparatus

Upon the operating and flow characteristics and efficacy of valves and their motors largely depends the success or non-success of automatic temperature control installations. It always requires *power* to operate valves and dampers. Temperature control *instruments* (other than the self-operating controllers) are not sources of power, and the modern trend is to take away from them even the function of *directly* governing the application of power. Recent developments are characterized by ingenious interpositions of relays—some instantaneous in their action, some purposely delayed—by greater flexibility of the power systems and by correct engineering of valves and valve-operating mechanisms—providing rangeability and adjustability with regard to the desired mode of control. The importance of these recent developments makes it necessary to devote this special section to some of them.

In recent years several companies have methodically accumulated engineering data and as a result have been able to design new series of operating devices and controlled valves. The new valves themselves are of distinct interest to the users of this Handbook, but even more so is the information on which their design was based. As was stated above, such information—or what there was of it—heretofore remained jealously guarded, and what little of it came out was applicable only to specific installations. The first systematic treatment appears above under "Modes of Control." It is *general* and is the author's own. The following *specific* discussions are, of necessity, largely based on the findings of several different manufacturers' engineering departments. It is indicative of the amount of work yet to be done that in each of the original manuscripts and bulletins received from different manufacturers there appear statements at variance with those contained in others. Temperature control engineering, evidently, is a young science indeed—to most practitioners only an art, to some a mere knack born of hard experience.

As in the case of radiation and optical pyrometers, the most convenient classification is simply into the various *makes*. In outside appearance different makes of diaphragm-motor valves, for instance, might look much alike, but the obtainable modes of control would differ—not only because they are connected to different instruments but because they are differently engineered. The same applies to electric motor valve mechanisms.

*Engineering Editor

## Recent Control Valve Developments

Up to 1928 and '29, when the first significant developments in pyrometric control came out, together with improved electric valve operating mechanisms, the fluid relay temperature controllers provided the "best" control—all things considered, especially flexibility.. For a while they were eclipsed, but in 1930 they began to "come back." The method of attack followed by the instrument manufacturers did not involve new designs so much as refinements of various elements, some far removed from instruments.

In last month's instalment of this Handbook we gave little space to the final elements of control systems—the valves. As if in answer to this slight the Foxboro Company has just sent us an interesting treatise on control valves, bearing evidence of years of research on that one particular subject. Some extracts are reproduced below with very little editing. The engineering information which has been accumulated by that organization in the course of many years has been in actual use for three years and the Company states that its validity has been proved in practice. This is understandable on reading the entire treatise which sums up this information. We must, however, take issue with one of the major premises on which one line of argument is developed in the treatise: The assumption is made (though not stated in these exact words)that departures from normality are proportional to changes in demand. Reference to our discussions on pages 431, 438, 439 and 451, will show that this is not so. . It *cannot* be so. Excellent as is the principle of air operation, it has precisely the one significant limitation that it cannot recognize rate and direction of change in demand. This criticism, however, affects only some of the introductory remarks in the following discussion.

When controllers were first developed it did not seem necessary to consider any particular characteristics for controlled valves other than service requirements. Experience and the more complex control problems brought the realization that the controlled valve must have certain definite characteristics, particularly with reference to flow. Controlled valves fall roughly into two classifications: those for open and shut action and those for throttling or floating action.

"Open and shut action" is used to describe the reactions of valves that in operation are either wide open or completely closed in distinction to "floating or throttling action" in which the valves are always open and constantly adjusted to compensate for variations in conditions or changes in demand. Valve reactions have as much to do with the control instrument and the process as with the valve design, but usually "open and shut action" can be obtained with balanced or single bevel-seated valves and "throttling or floating valve action" requires valves with desirable flow characteristics.

It is possible to use *valves* designed for throttling action on open and shut applications, because it is the control instrument that produces the valve reactions. On the other hand, it would be impossible to use valves designed for open and shut reaction on floating action applications, because the valve would not respond to the "floating" characteristics of the instrument.

In valves designed for open and shut action we are interested only in the flow at full opening. The size of the valve is important, but its flow characteristics are not. In valves designed for floating or throttling action we are interested both in the flow at all openings and particularly in the *rate of change* of flow. Flow characteristics, therefore, become very important.

A "floating action" controlled valve is under constant automatic control and is, therefore, more than a valve—it is an adjustable orifice or opening, adjusted by the reactions of the control instrument in accordance with the process demands. It is an integral part of the complete control equipment, and to work properly it must have various characteristics not found in ordinary valves. The degree of accuracy of control will be materially affected by a controlled valve lacking these characteristics.

"When the process requires floating or throttling valve action, the most important flow characteristic of a controlled valve" (according to the Foxboro Company) "is that the valve

produce equal *percentage change* in flow for equal increments of lift. This statement should be entirely clear when it is understood that in any control problem the supply of controlled medium must equal the demand; a ten percent change in demand requires a ten percent change in supply to establish equilibrium.

"At some particular control point the same percentage change in demand will always result in the same deviation-potential (force tending to cause the process to deviate from the control point).* The same deviation-potential will always cause a properly designed control instrument to effect the same change in valve lift.* Therefore, since an equal percentage change in demand must produce an equal percentage change in supply, it is obvious that equal increments of lift *must* produce equal percentage changes in flow.

"Foxboro engineers designed a controlled valve to give the flow characteristics (shown in Fig. 140) because they were familiar with the above mechanical requirements and because of the following important points.

"(1) A controlled valve having a parabolic characteristic flow curve *with its origin at zero* will not produce equal percentage changes of flow with equal increments of lift (refer to Curve No. 1, Fig. 142).

"(2) Controlled Valves in actual service will not produce flows according to their characteristic flow curves because of the effects of variation in pressure drop through the line, fittings and other equipment in the line of flow."

The following discussion will disclose why Foxboro has adopted a parabolic type of flow curve and a special V-port type of valve for general control application.

*Definition*—The expression "Controlled Valve" is descriptive of a valve capable of controlling flow. Webster's International Dictionary defines "control" in part as follows: "To check or regulate expenditure; to exercise restraining or directing influence; to dominate or regulate; to hold from action; to curb, subject and overpower."

In every sense of the word there is a meaning of retardation or restriction which gives to the controlled valve a function directly opposite to that desired of any other fitting or equipment placed in the line of flow. Therefore, it is logical to consider that controlled valves *restrict* flow and at the same time pass *only* the required quantity.

Before considering the functions that permit controlled valves to accomplish their purpose, a brief statement of the fundamentals of automatic control is necessary.

Every control problem—manual or automatic—is essentially one of controlling rate of flow, whether it is B. T. U.'s in temperature control; gas or liquid in pressure and flow control; or liquid in level control.

All applications of control require that the supply of controlled medium be equal to the demand, but the period of time over which these equalities must exist might vary widely.

Another determining factor in classifying control problems is the effect of "process lag." Process lag may be defined as *the influence of the element of time or rate of change upon the effect of any physical reaction within the process.* When automatically controlled, the most important physical reaction is that caused by the controlled valve itself.

The automatic control instrument must cause the correct reaction of the controlled valve to maintain the correct rate of flow for the desired control point. With air-operated controlled valve the reactions are caused by the instrument transmitting varying pressures to the diaphragm of the valve motor. The most important function of the instrument, therefore, is that it be capable of transmitting pressures to the controlled valve motor, which are proportional to the deviation-potential (force tending to cause the process to deviate from the control point.)* Correctly designed instruments with required sensitivity will react to the magnitude of the deviation-potential** and will counteract the deviation by transmitting a rate of change of pressure to the diaphragm motor, proportional to the rate of deviation. Control will be maintained if the controlled valve is capable of causing a rate of change of flow proportional to the rate of change of diaphragm pressure.

Assuming that the instrument used in connection with an air-operated controlled valve can transmit pressure to the diaphragm-motor of the controlled valve, in direct proportion to the tendency of the instrument to deviate from the control point, or transmit *rate of change* of pressure proportional to the *rate* of deviation, we are ready to consider the design and flow characteristics of a controlled valve capable of producing proportionate rates of change of flow.

The Foxboro air-operated valve motor is designed to give equal increments of valve-lift with equal increments of pressure change on the diaphragm; therefore, it is possible to disregard the diaphragm-motor as well as the instrument and plot flow against valve-lift, to represent the flows produced by the instrument itself.

*These statements imply a degree of intelligence not possessed by instruments responding to temperature. See comments above.—M.F.B.

**Provided this "deviation potential" corresponds always and exactly to departure of temperature from setting point.—M.F.B.

*Flow Characteristics*—In the preliminary analysis of controlled-valve flow characteristics, external influences such as pressure drop in line and fittings are disregarded and the controlled valve is considered as an adjustable orifice or opening. Under these assumptions such an opening will have a certain constant flow efficiency or coefficient, and the hydraulic formula shows that the quantity of flow is proportional to the area times the square root of the pressure drop. The instrument must, therefore, adjust the lift of the valve to obtain an area of port opening sufficient to permit the required flow under the conditions of pressure differential existing immediately up- and down-stream from the opening. For a given quantity of flow, the position of the valve within its total lift would of course be *inversely* proportional to its size, or, in other words, the larger the valve the less the lift; the smaller the valve, the greater the lift.

Regardless of its size or position of lift, equal increments of total lift must produce equal percentage changes in flow. For example, a change in lift from a position represented by 5% to a position represented by 10% of the total lift, should give the same *percentage* increase in flow as a change from 90% to 95% of the total lift. The importance of such a relationship will be readily appreciated when it is considered that the controlled valve is installed in the line of flow to compensate for *changes in pressure* either up or down-stream from the controlled valve, as well as to cause changes in flow to meet changes of demand in the process.

Variations in operating conditions require that the valve have rangeability, but the process demands that it be consistent in its effects, regardless of the position in which it is required to operate. Practical rangeability can be obtained only when equal increments of total lift produce equal percentage changes in flow.

Such relations would be expressed by a curve plotted from an equation of the form:

$$Y = C \times \log AX$$

Y = per cent of total lift

X = per cent of total flow

C and A = Constants, depending upon the units of the scale.

If correct relative values are assigned to C and A, so that X and Y may be expressed in percentages of their totals, certain values of X can be substituted, which will meet the conditions given in the example above. Substituting a value of 100 for C and 0.1 for A the equation becomes:

$$Y = 100 \times \log 0.1\,X$$

To increase a flow represented by 11.22% of total flow, by 12.2% (a flow represented by 12.59%) the valve must move from a position represented by

$$(100\% \times \log 0.1 \times 11.22) = 5\% \text{ of lift}$$

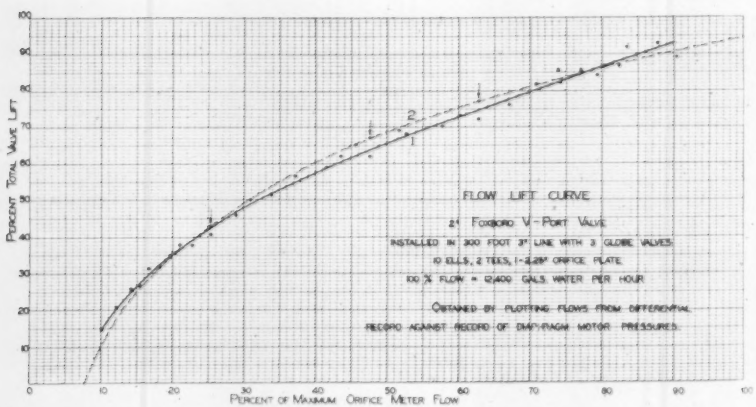

PERCENT TOTAL VALVE LIFT
PERCENT OF MAXIMUM ORIFICE METER FLOW
FLOW LIFT CURVE
2" FOXBORO V-PORT VALVE
INSTALLED IN 300 FOOT 3" LINE WITH 3 GLOBE VALVES
10 ELLS, 2 TEES, 1-2.28" ORIFICE PLATE
100 % FLOW = 12400 GALS. WATER PER HOUR
OBTAINED BY PLOTTING FLOWS FROM DIFFERENTIAL
RECORD AGAINST RECORD OF DIAPHRAGM MOTOR PRESSURES

Fig. 140. Flow characteristics of V-port control valve

(1) Solid line = Average of actual flow values taken at intervals over sufficient period of time to represent full rangeability of controlled valve. (2) Dotted line = Perfect percentage curve having percentage increases equal to average of curve (1).

Note by manufacturer: We are plotting per cent of total valve lift against a positive value scale (per cent of Maximum Orifice Meter Flow) not per cent of valve flow. For this reason changes in pressure drop, across the entire system of line, fittings, orifice plate and controlled valve, will cause the values of lift to vary for the same values of flow, but the general characteristics will remain the same. (See lift values for flow values of 25%—47% and 62%. Variations in data points from the average values shown by solid line curve are due to these independent variations in pressure drop, thus they represent points on curves of slightly different maximum lift values, but the general characteristics would be identical to the average curve. (*The Foxboro Co.*)

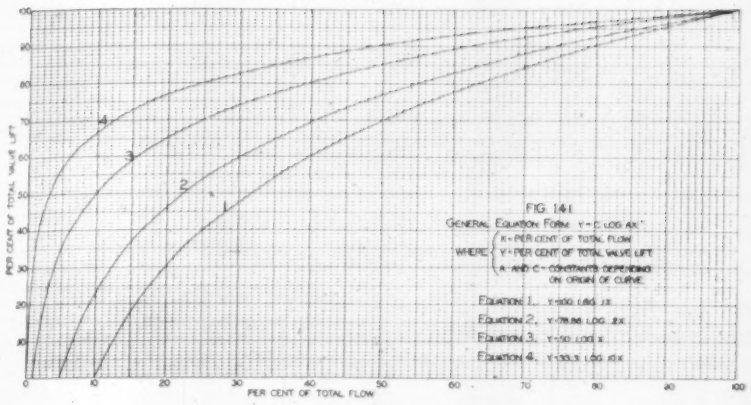

PER CENT OF TOTAL VALVE LIFT
PER CENT OF TOTAL FLOW
FIG. 141
GENERAL EQUATION FORM Y = C LOG AX
WHERE: X = PER CENT OF TOTAL FLOW
Y = PER CENT OF TOTAL VALVE LIFT
A AND C = CONSTANTS DEPENDING ON ORIGIN OF CURVE
EQUATION 1, Y = 100 LOG 12X
EQUATION 2, Y = 79.86 LOG 2X
EQUATION 3, Y = 50 LOG X
EQUATION 4, Y = 33.3 LOG 10X
1
2
3
4

Fig. 141

to a position represented by

$$(100\% \times \log 0.1 \times 12.59) = 10\% \text{ of lift}$$

If the original flow had been 79.43% of the total flow, a 12.2% increase (a flow represented by 89.12%) would require the valve to move from a position represented by

$$(100\% \times \log 0.1 \times 79.43) = 90\% \text{ of lift}$$

to a position represented by

$$(100\% \times \log 0.1 \times 89.12) = 95\% \text{ of lift}$$

This example represents values from Curve No. 1 of Fig. 141. The same X values may be picked up from the other curves on Fig. 141 and when substituted in the equation will give equal increments of lifts, but these increments will be smaller for each successive curve. The curves shown on Fig. 141 represent four curves of the general form $Y = C \times \log AX$ except that different relative values are used for C and A.

An examination of the mathematical equation ($Y = C \times \log AX$), shows that in order for X (the flow) to have a value of zero, Y (the lift) must have the imaginary value of minus infinity, since the logarithm of zero is minus infinity. All the curves on Fig. 141 give equal percentage increases in flow with equal increments of lift and they differ only in their value of X, when Y is equal to zero. The nearer X is made to approach zero, the greater will be the percentage of total lift required to produce the small percentages of flow. Fig. 141 graphically represents this relationship. Curve No. 1 shows that approximately 18% of the total lift is required to pass 15% of the total flow. The greater curves show that 15% is passed: by 37% of lift on Curve No. 2; by 59% of lift on Curve No. 3; and by 73% of lift on Curve No. 4.

*Other Curves with Desirable Characteristics*—An empirical study of curves, with other possible functions of X and Y, shows that a curve of the parabolic type is very similar to Curve No. 1 or No. 2 of Fig. 141, if the origin of this parabolic curve is located at some value between 5 and 8% of the X scale. The equation for this curve is

$$Y^2 = AX$$

Using a value of $A = 100$ in the parabolic formula ($Y^2 = AX$), X and Y may be expressed in percentages of their totals and the origin of the curve will be at zero. To plot parabolas in which X has values greater than zero when Y equals zero, the equation becomes:

$$Y^2 = 100 \times \frac{X - C}{1 - \frac{C}{100}}$$

C = the value of X when Y equals zero

Curve No. 1, Fig. 142 (p. 516), is an ordinary parabolic curve plotted from the equation $Y^2 = 100X$, thus its origin is at zero. Curve No. 1A is the perfect percentage curve which has its origin at 0.1 (practically zero). Curve No. 2 and No. 2A show the relations of the functions of $Y^2 = AX$ and $Y = C \times \log AX$, when their constants are such that they have three points in common, distributed over the X axis. Their equations are given in the lower right-hand corner of Fig. 142.

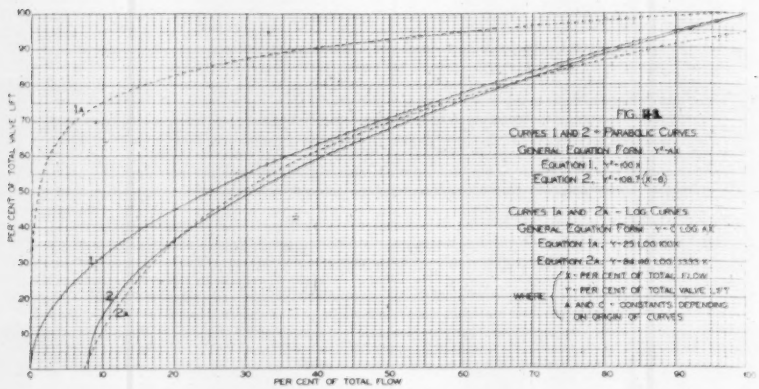

PER CENT OF TOTAL VALVE LIFT
PER CENT OF TOTAL FLOW
1A
1
2
2A
FIG. 142
CURVES 1 AND 2 = PARABOLIC CURVES
GENERAL EQUATION FORM Y=AX
EQUATION 1. Y=100X
EQUATION 2. Y=108.7(X-8)
CURVES 1A AND 2A = LOG CURVES
GENERAL EQUATION FORM Y=C LOG AX
EQUATION 1A: Y=25 LOG 100X
EQUATION 2A: Y=84.66 LOG 133.3X
WHERE X = PER CENT OF TOTAL FLOW
Y = PER CENT OF TOTAL VALVE LIFT
A AND C = CONSTANTS DEPENDING ON ORIGIN OF CURVES

Fig. 142

A comparison of the percentage relations between Curves No. 1 and No. 2 is shown in the following example: The change in lift from 5% to 15% on Curve No. 1 gives a *percentage increase* in flow of 800%, and a change of lift from 85% to 95% gives a change in flow of 24.9% or a variation of 32 to 1. Referring to Curve No. 2 (which has its origin at 8%), a change in lift from 5% to 15% gives a percentage increase of 22.5%, and a change in lift from 85% to 95% gives a percentage increase of 22.2%. It is evident, therefore, that the ordinary parabolic curve with origin at zero is very unsatisfactory in producing equal percentage changes of flow with equal increments of lift. However, around fifty per cent flow values the percentage increase for the same increment of lift may run as high as 27.5%.

Although the above curves are mathematical, they represent flow characteristics *when* a constant pressure drop is maintained across the valve *orifice*. A study of these curves has shown that a parabolic type of curve is quite desirable *provided* its origin is located at the proper point on the X axis.

*Valve Design*—Consideration is now given to the design of a practical type of valve to produce this characteristic flow curve. More constant relationship between lifts and flow can be obtained by using high lift to represent required flow. In designing a valve for high lift, it is of course desirable to use some piston type of valve plunger. This piston or plunger may be shaped to give parabolic characteristics by machining it to produce the desired areas between the wall of the piston and the seat ring, or by using a cylindrical piston with desirable port areas in the skirt.

In the shaped plunger type, extremely narrow annular openings must be tolerated in order to produce the small areas necessary for small flows. The perimeters of these narrow annular openings are enormous compared to their areas, which causes wire-drawing . . . If, in an effort to reduce the velocity, the designer should use large port areas, it would mean only that the valve must be in a more nearly closed position to pass the same quantity of fluid, under the same conditions. The valve should be sufficiently small so that it will not operate in a nearly closed position at normal flow.

A circle has the smallest ratio of perimeter to area but a controlled valve with an adjustable circular opening is impractical. In any piston type of valve plunger it is highly desirable to keep the diameter of the piston a minimum commensurate with strength and required port area. An equilateral triangle has a small and constant ratio of perimeter to unit area and permits adjustment of its area by one motion along its altitude. It, therefore, has a decided advantage in maintaining its flow characteristics under condition of unavoidable high velocity.

Fortunately this same geometrical figure, the triangle, which has certain advantages under high velocities, *also produces a parabolic curve if its altitude is plotted against its area.*

It has been shown that if parabolic curves are to be used for valve characteristics, it is desirable that the valve have a certain initial flow in addition to the flow through the port area. The mechanical construction of a V-port valve provides that there must be some space between the seat ring and the piston in order to eliminate binding and to permit free operation of the plunger. Also there must be some manufacturing tolerances in the sharpness of the apexes of the V's. Calculations show that when these clearances, together with the

initial areas of the apexes, are made sufficient to give the desired initial flow, they are still practical as far as the mechanical and manufacturing construction of the valve is concerned.

*Advantages of Renewable Plungers*—If the computed valve size proves too large in actual service, it is a simple operation to replace the original plunger with one of smaller port area. In emergency it has proved practical to close a sufficient number of ports to obtain the correct effective valve size.

*Rangeability of Controlled Valve*—The ratio of the maximum controllable flow to minimum controllable flow gives the rangeability of controlled valves. This value must be large enough to permit the controlled valve to "dominate" all other factors tending to control or *influence the flow.*

Curve No. 2, Fig. 142, shows that the range through which a practical parabolic flow curve gives equal percentage changes in flow with equal increments of lift is from about 8% to 100%, or a rangeability of better than 12 to 1.

This rangeability represents the permissible variations in pressure drops as well as variations in flow, and with either given, it is a simple matter to calculate the permissible variations of the other. For example, knowing that area is directly proportional to the flow and inversely proportional to the square root of the pressure drop, it follows that with a valve having a rangeability of 12 to 1 and a condition requiring a rangeability in flow of 4 to 1, a variation of 9 to 1 in pressure drop could be tolerated since

$$\frac{12}{4} = \sqrt{\text{pressure drop or } \left[\left(\frac{12}{4}\right)^2 = 9\right]}$$

When $\frac{\text{maximum flow}}{\text{minimum flow}} = F_r$ (rangeability of flow); $\frac{\text{max. } P_1^* - \text{min. } P_2}{\text{min. } P_1 - \text{max. } P_2} = P_r$ (rangeability of pressure drop); and $V_r$ = rangeability of controlled valve; the permissible variation of one in terms of the others can be determined from the simple formula

$$P_r = \left(\frac{V_r}{F_r}\right)^2$$

It is apparent that maximum $P_2$ must be less than minimum $P_1$ or $P_r$ will have a minus value and give imaginary values to $F_r$ and $V_r$.

Changing the above formula to the form $V_r = F_r \sqrt{P_r}$ it is apparent that excessive maximum flows or diminutive pressure drops, at maximum flows, will result in excessive values of $V_r$. Any values of $V_r$ greater than 12 will mean that conditions may be outside the practical range of a parabolic characteristic, and the data should be investigated to determine possible excessive values of maximum flow or diminutive values of pressure drop at maximum flow. If, however, the investigation proves that the rangeability must exceed 12, the minimum value of X can be calculated from the simple formula, minimum $X = \frac{100\%}{V_r}$. The minimum value of X may be used to determine the necessary logarithmic curve of the form $Y = C \times \log AX$, Fig. 141. Unless the required curve lies between Curve 2 and Curve 3 (i. e., minimum X is greater than 1 or $V_r$ is less than 100) it is apparent that the flow characteristics are impractical because of probable excessive wire-drawing at low values of lift and the possible excessive influences of pressure drop through line and fittings. To appreciate the importance of the latter it is necessary only to recall that pressure drop is proportional to the *square* of the velocity. Thus a rangeability of 25 to 1 in flow would require a rangeability of 625 to 1 in pressure drop through the line, fittings, and other equipment in the line of flow.

If such extreme rangeabilities are to be met, it is absolutely necessary that the pressure drop through the line at maximum flow does not greatly exceed the pressure drop across the valve, at maximum flow.

*Influence of Pressure Drop through Line and Fittings*—The flow curves referred to above have all been mathematical expressions of the relations of X and Y and are properly called flow characteristics, but it must be understood that the flow values represented by characteristic flow curves, will be produced *only when* constant pressure drop is obtained across the valve port area.

In actual applications controlled valves are always installed in lines and the locations of reasonably constant pressure are always some distance away. The practical pressure drop

*$P_1$ = Upstream pressure. $P_2$ = Downstream pressure.

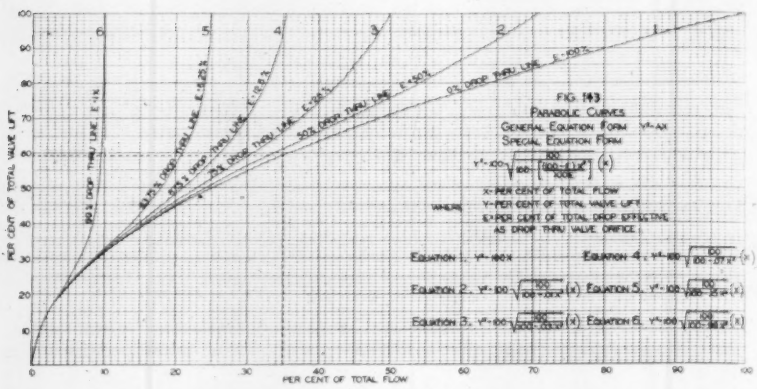



Fig. 143

available across the valve ports can only be equal to the minimum pressure difference between the two locations of reasonably constant pressure, *minus* the pressure drop through the line, fittings, or any other equipment existing between these locations. Considering that these points are often far apart and that the pressure drop through all fittings or equipment is directly proportional to the distance and to the *square* of the velocity, it is evident that the controlled valve is not the only factor tending to control the flow.

According to Webster's definition of control, a controlled valve must be capable of "dominating," "subjecting," and "overpowering" all other factors tending to control the flow.

Referring to Fig. 143, Curves Nos. 2, 3, 4, 5, and 6 graphically illustrate how the flow characteristics represented by Curve No. 1 may be influenced by external fittings in the line of flow, robbing the controlled valve of pressure drop at high flows.

For example, if the parabolic Curve No. 1 represents a flow through a controlled valve of such port area that a 10 lb. pressure drop would pass 100 gallons per minute, when the valve was fully open, and fittings were installed in the line of flow such that they absorbed 50% of the available 10 lbs. pressure drop, the flow characteristics of the entire system would be represented by Curve No. 2. Under these conditions the controlled valve would have 50% of the available pressure drop and the flow would be proportional to the square root of $\frac{50\%}{100\%}$, or the new flow would be $100\% \times \sqrt{\frac{50\%}{100\%}} = 70.7\%$ of original flow.

Other points in these curves are determined by a similar mathematical calculation involving the hydraulic flow formula. For example if this controlled valve is required to pass 50% of its full capacity (50% of 70.7% =35.35%), the line and fittings would have $\left(\frac{50\%}{100\%}\right)^2 \times$ 5 lbs. = 1.25 lbs. drop and the controlled valve would have the remaining 8.75 lbs. drop. The controlled valve therefore has 87.5% of the available 10 lbs. drop and the lift would correspond to the lift on Curve No. 1, required to pass 35.35% multiplied by $\sqrt[4]{\frac{100\%}{87.5\%}}$ that is 59.45% ×1.034 =61.5%.

Curves Nos. 3, 4 5, and 6, Fig. 143 are determined in the same manner and represent respectively characteristics in which 75%, 87.5%, 93.75%, and 99% of the total available pressure drop is effective as drop through the line and fittings. Thus, the effective pressure drop across the valve ("E" in the equations) is equal to the full available pressure drop *minus* the pressure drop through the line and fittings.

*Independent Variations in Pressure Drop*—Inasmuch as a single curve in one plane will represent only two variables, it is necessary to assume constant pressure drop in plotting flow characteristics. However, this pressure drop can not be considered as existing only across the controlled valve, but we must consider constant pressure existing at two remote points

—one up stream and one downstream from the controlled valve. Under these conditions we could represent the effect of fittings or other resistances in the line of flow with the controlled valve.

If in actual operation, these points of assumed equal pressure actually vary independently of the flow, the variations would be represented as caused by additional or less fittings or resistances before or after these points. If the variations cause greater pressure difference between the two points, the effect would be the same as removing some of the resistance between the two points. Such variations in resistances of external fittings cause the curves to shift their values of lift for the same flow. It is evident that the variation in pressure drop between these two points does not affect the pressure drop through the line and fittings as long as the flow remains constant; but the entire variation in pressure drop is effective in varying the pressure drop across the controlled valve by the whole amount, thus we have changed the ratio of pressure drop through the valve to pressure drop through the line and fittings for the same conditions of flow. Referring to Fig. 143, this would correspond to locating the same flow values on the various curves and reading the required lift on the lift scale.

*Characteristic Flow Curves and Their Mathematical Equations*—The only factor that can prevent a controlled valve plotting a characteristic curve identical to the curve representing the relation of its areas to its lifts, is valve-body resistance which prevents the port area from receiving the full available pressure drop. This resistance obeys the hydraulic formula and may therefore be expressed mathematically. Variations in efficiency resulting from openings, of various shapes or sizes, come under this same classification and the curves will still obey the general formula. Because of this fact all curves represented so far have been expressed as mathematical curves, thus avoiding errors and innumerable tests and permitting the correctness of the curves to be checked mathematically.

A characteristic flow curve determined by actual experiment and plotted on the same scale with the mathematical or empirical curve, representing the relations of valve lift to valve area, would show a marked relationship between the percentage of valve-lift and the percentage of deviation of these curves. An empirical study of the relations of their X values would give correct values to the constant of the general equation and thus make it possible to express, mathematically, the resistance effect of valve body or external fittings.

As an example, a controlled valve may be used of such construction that the relation of valve-lifts to port areas plot a parabola such as Curve No. 1, Fig. 143. If the actual characteristic flow curve of this valve is similar to Curve No. 2, Fig. 143, the port area of this valve must be so large that the valve body resistance robs the valve port of approximately 59% of the total drop when the valve is wide open.

In the ordinary bevel-seated valve, areas are directly proportional to lift. Thus the general formula would plot a straight line, the slope of which would depend on the values of the X and Y scale. The maximum port areas of these valves often greatly exceed the line area. Thus the pressure drop across the valve body greatly exceeds the pressure drop across the port area when the valve is wide open. This type of valve would of course pass more fluid, but the flow characteristics would be very similar to Curves No. 5 and No. 6 of Fig. 143, except that the flow values of 25% on Curve No. 5 or 10% on Curve No. 6 would represent 100% flows.

The upward trend of the characteristic flow curves of ordinary bevel-seated valves is a result of the fact that the pressure drop across the port area is very small compared to the pressure drop across the valve body.

*Compensating for the Effect of Pressure Drop through Line and Fittings*—Referring to Fig. 143, it can be seen that Curve No. 4, and especially Curves No. 5 and No. 6, would pass very little increased flow if the lifts were increased indefinitely or if the valve was completely removed from the line and replaced by a short nipple the size of the line. Under these conditions the external influences have become the controlling factor and the controlled valve has practically lost its ability to "dominate" or "overpower."

One noticeable characteristic of the curves on Fig. 143 is the decided tendency to coincide at the lower positions of lift. For example, at a lift of 35% the flow value of Curve No. 5 is within 8½% of Curve No. 1; at a lift of 60% Curve No. 2 is within 6% and Curve No. 3 is within 15% of Curve No. 1. Therefore, if conditions of pressure drop and flow would permit the use of that section of Fig. 143 bounded by a flow of 35% and a lift of 59.16%, the controlled valve would more nearly maintain its flow characteristics throughout the entire range. *The use of smaller port areas would accomplish the same result.*

The dotted section of Fig. 143 shows that efforts to increase flows by increasing the lift (or valve area) will cause wide deviation of these curves unless the effects of external fittings are comparatively small, or the major portion of the total available pressure drop at high flow

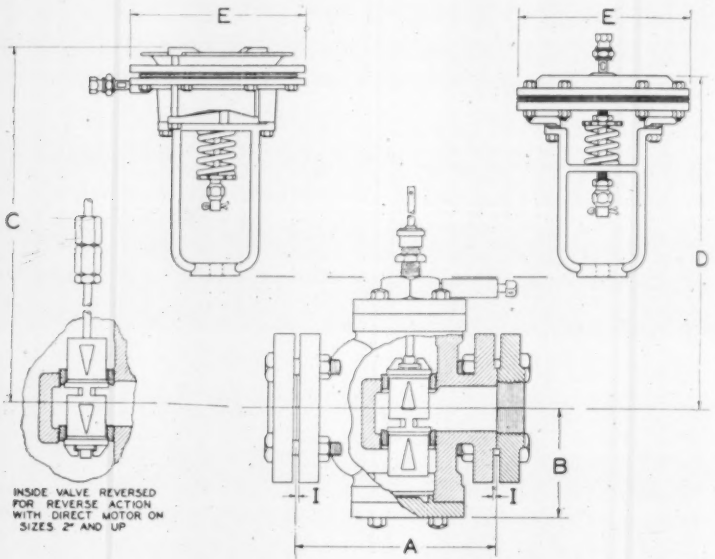



Fig. 144. Diaphragm-motor valve recently developed especially for providing suitable characteristics for automatic temperature control applications. Plunger has V-ports whose area was worked out as explained in the accompanying text. Bonnet equipped with Merco Nordstrom type valve-stem lubrication. Manufacturer designates as "direct-acting" the valves which close on failure of compressed air and as "reverse-acting" those which open when air pressure is relieved. (*The Foxboro Company.*)

is through the controlled valve. If, at maximum flow, the major portion of the available pressure drop is through the valve, the flow may be increased by increasing the valve size, or if the line is short and relatively free from fittings, the port areas may be increased when the valve is the same size as the line.

The larger the line with respect to the valve the more rangeability the valve will have. Since the pressure drop increases as the square of the velocity and the velocity is inversely proportional to the square of the pipe diameter, the pressure drop is *inversely* proportional to the *fourth power* of the pipe diameter, and it is obvious that the diameter would be more important than the length of the pipe.

*Impracticability of By-pass Adjustment with Throttling Action Control*—One of the major purposes of controlled valves is to compensate for unavoidable variations in pressure up and downstream from the controlled valve. These variations may be due to changes in velocities, as well as pressure variations at the source or final downstream point—such as steam pressure at the boiler house or in the exhaust steam line.

Regardless of their cause these variations in pressure drop greatly affect the permissible flow variations of the controlled valve. The relations of variations in pressure drop, flow and rangeability have been discussed in detail under "Rangeability of Controlled Valve."

The rangeability of control obtained with a controlled valve *in actual application* is represented by the ratio of maximum controllable flow to minimum controllable flow. Any attempt to use a by-pass will increase both maximum and minimum controllable flows, but unless the controlled valve is actually too small to produce the required flow, the extra flow through the by-pass is not required, and the increase in maximum controllable flow is never used. Consequently the operating rangeability of the valve is reduced to an even greater degree.

It is interesting to note that, as its origin moves to the right, the percentage curve completely crosses the parabolic curve and the curve does not express nearly as correct a percentage relationship as it did in its original position with no flow through the by-pass.

Even if the by-pass is adjusted because the controlled valve is too small, the resulting flow characteristic curve and the perfect percentage curve deviate, and the greater the proportion of flow through the by-pass the greater the deviation.

The most serious effect of by-pass adjustment is indicated in the change of rangeability of the controlled valve. If, to a rangeability of 12½ to 1, a 50% adjustment is made in the by-pass, this rangeability is reduced to 2 to 1; and if 75% is permitted to flow through the by-pass, the rangeability is reduced to 1.33 to 1 . . .

. . . In conclusion, this study of by-pass adjustments has indicated that, if the valve possessed desirable flow characteristics originally, it is undesirable to make by-pass adjustments, and that by-pass adjustments are possible only under those conditions that require an extremely small rangeability of the controlled valve. The apparent enthusiasm over by-pass adjustment is the result of having been able to correct undesirable flow characteristics by adjusting by-passes on applications, so *continuously uniform* in their conditions as to require practically *no rangeability* in the controlled valve. Any change in conditions would require readjustment of the by-pass.

In open and shut application flow characteristics are of no importance, so valves can be pinched ahead of the controlled valve, when the process is adversely affected by excessive fluctuations of flow. This represents conditions entirely different from those encountered in throttling control and should be recognized as such.

## Recent Developments in Electro-Mechanical Valve Operating Mechanisms

References have been made to these developments. The achievements of two more organizations are of special interest: the Automatic Temperature Control Company in the field of pyrometric control, and the Bailey Meter Company in the field of large installations requiring considerable power and ruggedness.

The Automatic Temperature Control Company has contributed for this Handbook a great deal of material from which it is only possible to give brief extracts, whose interest lies especially in their relation to the above discussion on Modes of Control. Before coming to these specific discussions, a general discussion of such devices, written for this Handbook by the Brown Instrument Company, is eminently in order:

The application of an automatic control device to a process is usually a problem of controlling the supply of a medium in response to some measured change of conditions in the process itself. Under favorable conditions the control instrument changes the position of the control device, a valve for example, only when the demand of the process itself requires such a change. Many temperature control applications, however, require a continual shifting of the control valve position, although the demand of the process may be quite steady and the process may be one which naturally tends to balance itself. It is not always possible to eliminate some of the variables entering into the process. Changes in the temperature caused by these variables must then be detected later on in the process and the necessary adjustments made to counteract their effects. This introduces a condition which may be termed "Process Lag" because it represents a time lag over which we have no control.

Motor-driven control valves naturally lend themselves to use in conjunction with pyrometer control instruments, and offer a flexibility which cannot be easily obtained in other systems. The requirements for various power ratings are met by changing the size of the motor. The control mechanism may be located any distance from the control instrument without introducing the slightest time lag in the responsiveness of the equipment. This same flexibility allows the grouping of a large number of instruments in a central control house and thus simplifies the problem of installation.

In choosing the proper type of control equipment to use on a specific application, we must analyze the process which is to be controlled, and in addition should decide what operating characteristics the control mechanism must have to meet the particular requirements of the problem in hand. Closeness of control is naturally desirable, and is the real object in view, but it must be accomplished without sacrificing other factors which are also a measure of its success. Among these other factors are

Convenient means of adjustment,

Capacity to maintain stable operation with little attention,

Correct adjustment of fuel supply,

Reasonable cost.

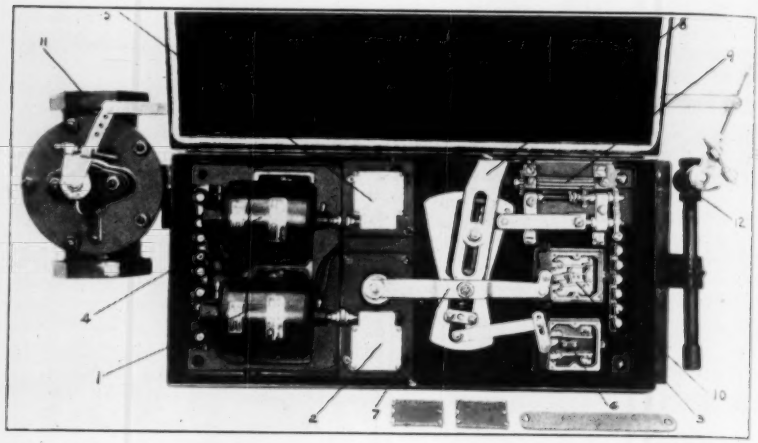


Fig. 145. Motor-operated balancing three-position valve-operating mechanism ("Type 310"). Especially adapted to furnace control where the fuel demand varies and where a time interval is required for the pyrometer to respond after fuel valves have been adjusted. The three-position switch on the initial stroke motor halves the stroke, when temperature is above or below normal, it anticipates reaching the holding point and thus reduces the tendency to under or over shoot; and while at the holding temperature, the valve settings are stationary and fuel supply is balanced to the demand.

1—Initial stroke motor
2—Initial stroke motor gear unit
3—Initial stroke motor switch
4—Balancing motor
5—Balancing motor gear unit
6—Balancing motor switch
7—Crank lever
8—Main operating lever
9—Adjustable time clutch
10—Terminals
11—Air valve
12—Oil valve

(*Automatic Temperature Control Co.*)

If adjustments are easy to make, the operator is inclined to overlook other limitations in the equipment, whereas if they are difficult, or even complicated, he will naturally take the easiest step, which is to shut off the control and make the necessary adjustments manually. However, if the equipment requires change in adjustment for every small change in operating conditions, the operator soon learns that the equipment makes extra work and as a result reverts to hand control.

Control mechanisms may be broadly divided into two general groups. In the first group are those types which move the control valve through a definite adjustable step. This step may occur infrequently or it may occur at fairly regular intervals. In practically all mechanisms of this type the lever completes its stroke in one continuous movement after the motor is energized by one of the control contacts in the instrument. The second group comprises those units which have a second motor whereby the operating range is increased and the necessity for manual adjustments, when appreciable changes occur in furnace demand or fuel line pressure, is eliminated.

The simplest type of control is the "On-and-Off" type of mechanism. This is applicable and entirely satisfactory where appreciable movements of the control valve are not objectionable. The valve movement is frequently reduced by adjusting the limit switches so that the movement of the valve from one position to the other will cause only a small change in the flow of fuel to the burners. This tends to reduce the surges and the resulting temperature control record will show a saw-tooth line of fairly small amplitude. Such a type of control is easily adjustable.

The "Three-Position" control mechanism has a middle or normal position, and has two distinct advantages as compared with the Two-Position, or On-and-Off type. The operating range of the control valve itself is increased, and the valve movement from the middle to the low or high position may be the equivalent of the stroke of a two-position mechanism, thus doubling the total range. The second advantage is in the "backing-off" effect produced when the control valve is moved to its center position from either direction. This tends to prevent "over-shooting," because the center position has a certain "width" and the temperature has an opportunity to line out on the center contact. Experience has shown that the Three-Position type of control mechanism will improve almost any control where the Two-Position type has formerly been successful in maintaining the temperature within satisfactory limits.

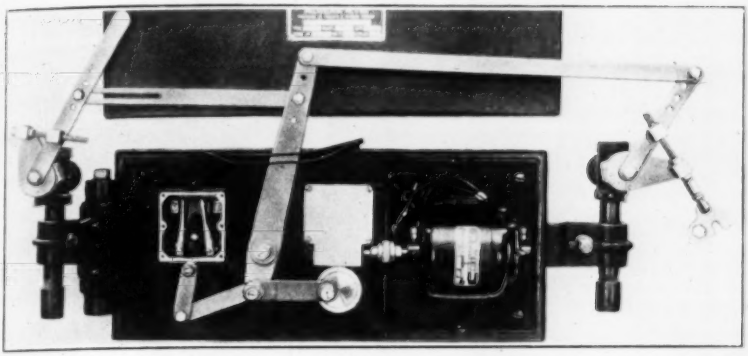


Fig. 146. Valve-operating mechanism equipped with V-port valves. Operating lever is moved to full left position when temperature is low, allowing by-pass valve to be manually opened. This valve is automatically closed when desired temperature is reached. (*Automatic Temperature Control Co.*)

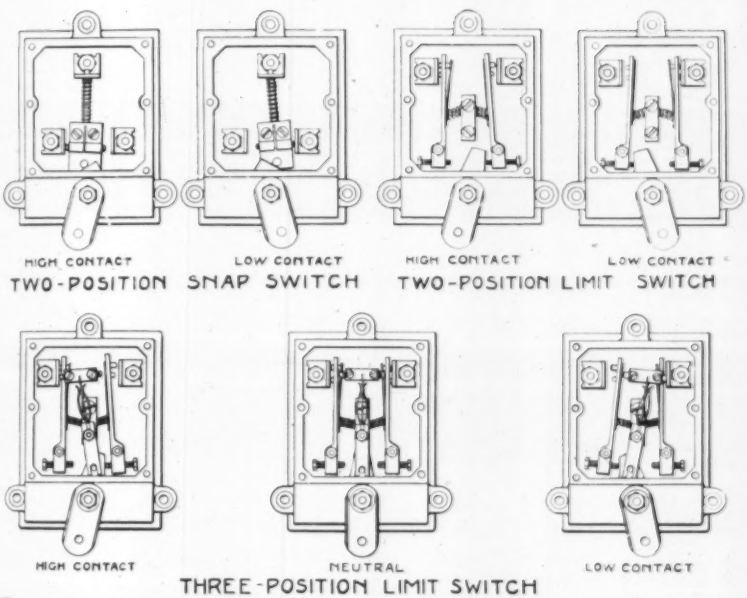



Fig. 147. Switches incorporated in valve-operating mechanisms, such as illustrated in Figs. 145 and 146. These switches have a great deal to do with the mode of control of the installation, but they in turn depend on the type of contact-making temperature controlling instrument. Note: Switches are shown in positions assumed after the stated contacts have been made. (*Automatic Temperature Control Co.*)

By adding a second motor to the control mechanism, the operating range of a three-position mechanism can be increased to cover the entire range of the control valve, thereby eliminating the necessity of manual adjustments when appreciable changes occur in furnace demand or fuel line pressure. The term "floating" three-position indicates that while the action of the mechanism is primarily that of a three-position type, the second motor enables the mechanism lever arm to take any position throughout its entire range of movement to correspond to the middle or normal position of the initial stroke motor. This type of mechanism combines the advantages of the simple three-position mechanism with the wide operating range of the

floating type. Its greatest field of usefulness is in those applications where operating conditions require a wide range in the control valve movement, but where the three-position movements of the valve are not objectionable. It can be used in combination with the same type of control instrument as the single-motor three-position mechanism.

On applications where there is a moderate process time lag an arrangement is provided whereby the balancing motor will not move the fuel valve until after the control instrument has had an opportunity to respond to the effect of the change in valve position made by the initial motor. This is done by providing a time-lag clutch between the floating motor and the mechanism lever arm. The floating motor can then operate for several depressions of the control instrument before the clutch engages to move the mechanism lever.

## Extracts from the discussions submitted by the Automatic Temperature Control Company now follow:

A big factor is that of time lag. We may illustrate its importance by a typical sequence of control operation: An unloaded heat treating furnace has a temperature of 1600° F. a load is placed in the furnace and the temperature naturally drops. The temperature is not indicated on the controlling pyrometer until possibly 30 to 45 seconds have elapsed. The actuating instrument, making its proper contact, opens the control valve a certain amount to supply additional fuel to the furnace to take care of the drop in temperature. This increased fuel supply is not enough to meet the increase in demand and the temperature continues to drop—what happens? The controlling valve is always behind in regulating the fuel supply and is continually hunting for the proper fuel supply to meet the furnace demands. Say that sufficient fuel has been supplied to the furnace and the temperature is gradually building up, the actuating pyrometer or instrument makes the proper contact for the full opening of valve position in order that the temperature will return to its desired value at 1600°. This is what is desired and the valve regulation will result in the temperature being reached. Due to the time lag, however, the desired temperature will be reached with the controlling valve in the full open position. This will result in a larger fuel supply than is required to maintain that temperture and overshooting naturally follows.

A remedy for this hunting and overshooting is a control valve which will anticipate any change of fuel required and will regulate the fuel valve so that just sufficient fuel is supplied to meet the normal furnace demands. The "three position" controller has these desired

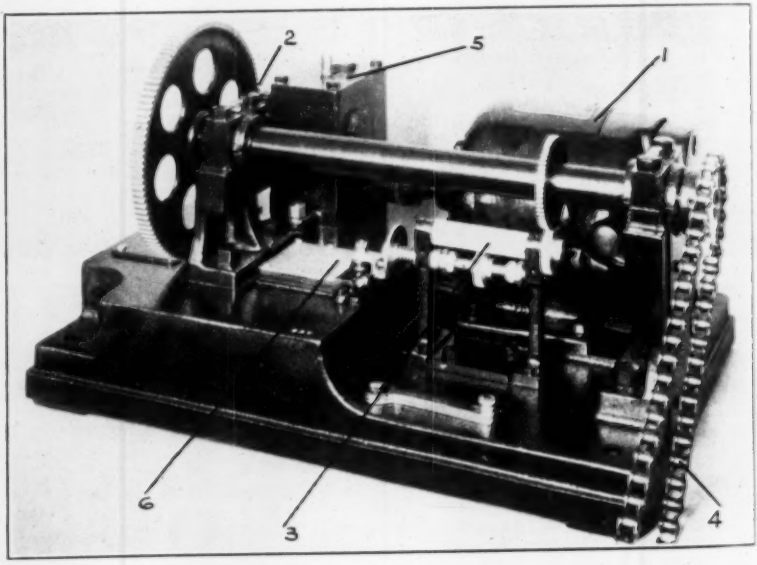



Fig. 148. Automatic reversing controller. Three-position initial stroke motor, time lag, compensating gearing and balancing follow-up motor. Switch covers and controller cover removed. 1—Reversible motor; 2—Change gears; 3—Adjustable switch drive mechanism; 4—Chain drive to valve, damper, etc.; 5—Gear reduction unit; 6—Limit switch. (*Automatic Temperature Control Co.*)

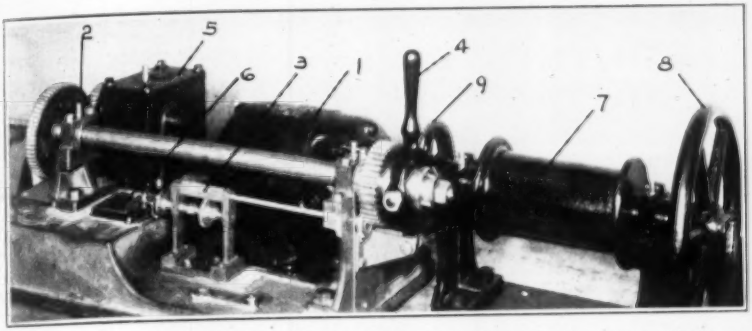



Fig. 149. Valve-operating mechanism equipped with winch and declutching mechanism to permit of hand operation. Construction designed for operating cold air mixing valves on blast furnace. 1—Reversible motor; 2—Change gears; 3—Adjustable switch drive mechanism; 4—Handle for declutching winch; 5—Gear reduction unit; 6—Limit switch; 7—Winch drum; 8—Handwheel for manual operation of winch; 9—Winch drive gears.
This controller is recommended where the load requires power and there is immediate response at the contact instrument to valve or damper adjustment. When the instrument makes its high or low contact, the motor operates to open or close the valves a step at a time. This mechanism can be furnished with sprocket and chain drive for operating large butterfly valves, with gear drive for operating large screw stem or lubricated plug valves and with lever arm mechanism where required. Numerous standard drive shaft speeds are available and the limit switch can be set to open motor circuit and stop drive shaft at from ¼ to 20 revolutions as necessary. (*Automatic Temperature Control Co.*)

features. The "throttling" or "balancing" controller has the desired features found in a three-position controller with the additional feature of being able to readjust this normal valve position to meet a change in the normal furnace fuel demands. This equipment operates so that if the temperature departs from normal, a very quick but positive change is made. If this does not correct the condition, after a set elapsed time, a continual adjustment is made. As soon as the temperature starts to return to the correct value, the correct normal for the controlling medium is immediately anticipated and the valve changed accordingly. This type of controller stabilizes conditions, prevents hunting and takes care of slow or fast changes and large or small changes in conditions.

The five types of controllers, listed below with a typical installation for each type, can be classified as giving five different "modes of control."

"Two-position" for single valve control where both an adjustable minimum and maximum opening is required, such as for gas-fired furnaces, operated on the pressure type one pipe system.

"On and Off" designed especially to operate a single valve or damper from fully or partly opened to a fully closed position. A by-pass is usually required.

"Floating" for regulation of pressure or level where there is a prompt response at the actuating instrument to valve, damper, or louver adjustment.

"Three-position" especially adapted to fuel fired furnaces where air must be proportioned to fuel to maintain proper combustion. Used also for one valve control where both an

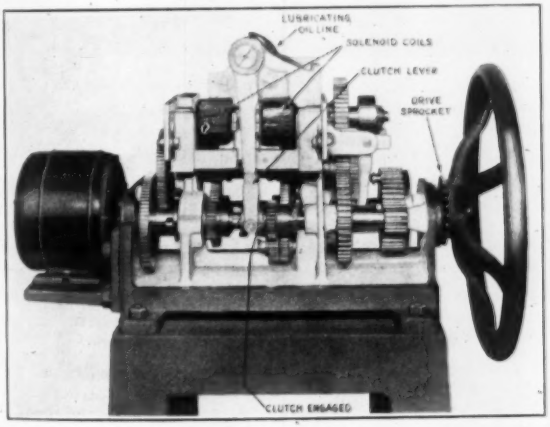



Fig. 150. Drive unit for operating valves, dampers, etc. in accordance with electrical impulses from contactors. Consists of a continuously running motor driving a system of gearing which functions to advance or retard the equipment as the "more" or "less" clutches are engaged when the corresponding solenoids are energized. A feature is protection against runaway conditions by means of time limits to prevent overtravel of control equipment. (*Bailey Meter Co.*)

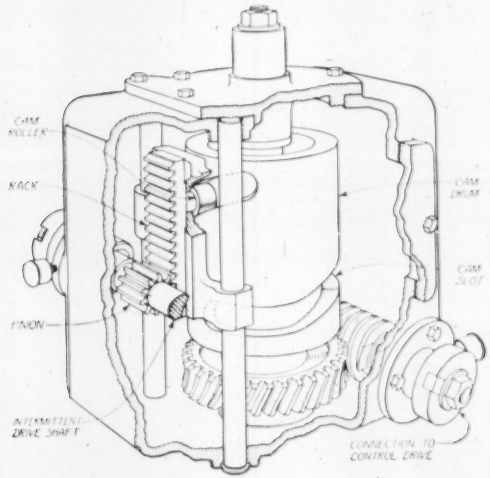



Fig. 151. Intermittent drive unit permitting operating damper below minimum fan speed. Especially applicable in some cases of combustion control where the characteristics curves for fuel and air are widely divergent, or where there is a wide difference in the change of rate of supply of fuel or air for a given percentage of control travel. A special cam gives straight-line characteristics or makes the characteristic control curve for the various factors more nearly parallel. (Bailey Meter Co.)

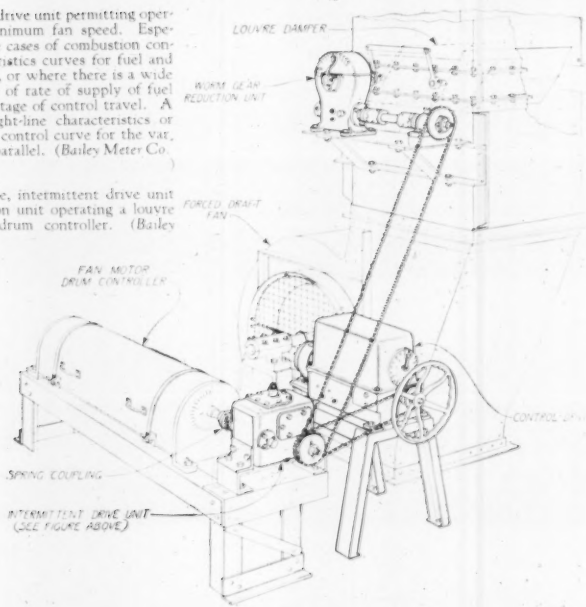



Fig. 152. Control drive, intermittent drive unit and worm gear reduction unit operating a louvre damper and 31-point drum controller. (Bailey Meter Co.)

adjustable minimum and maximum opening is required such as for gas-fired furnaces operated on the pressure type one pipe system.

"Balancing three-position" especially adapted to fuel fired furnaces where air must be proportioned to fuel to maintain proper combustion and where the fuel demand varies, requiring an additional adjustment of the valve.

These types of motor-operated controllers have the maximum power available at the *start* of the valve movement, in contrast to the solenoid type "Off and On" controller which operates with a snap action, applying the maximum power at the end of the valve movement.

A characteristic of the reversing or "floating" controller is that it is not ordinarily satisfactory for temperature regulation due to the time lag of the actuating instrument, which results in controller hunting.

The following suggestions have proved quite helpful in oil installations of automatic control equipment:

1—The oil must be thin enough to flow freely at all times and kept in this condition by means of a heating system.

2—Good combustion and good control of oil burners is easily obtained if the control valves are mounted below the burner level. For this type of mounting there is little or no tendency for the oil in the pipe line between the control valves and the burners to drain out while the burners are at a minimum setting.

3—The continual hand manipulation of the oil valves as is a prevailing operation to obtain proper gasification in the combustion block, is generally due, not to clogging burners, clogging needle valves or strainers, but to the improper installations or applications of burners or burner accessories.

4—Oil burners controlled from one set of control valves should have the same operating characteristics.

5—The necessity for adjusting individual burners under automatic control should be eliminated.

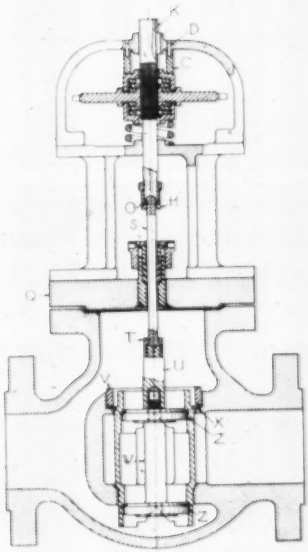



Fig. 153. Control valve applicable where straight-line flow characteristic is required in fluid control—gas, air, steam, water, etc. Driven by control drive of the electrical type illustrated in Fig. 150. (Bailey Meter Co.)

6—A strainer should always be placed before the control valve.

7—It is good practice to place hand valves in the by-pass line so that additional fuel may be supplied to the burners when starting up without disturbing the adjustment of the automatic control valve.

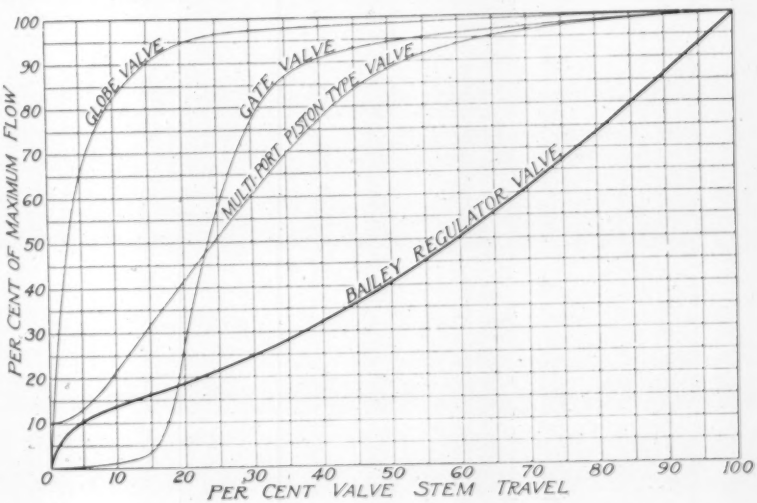



Fig. 154. Characteristic flow curves for various types of valve. The heavy curve applies to the valve illustrated in Fig. 153. (Bailey Meter Co.)

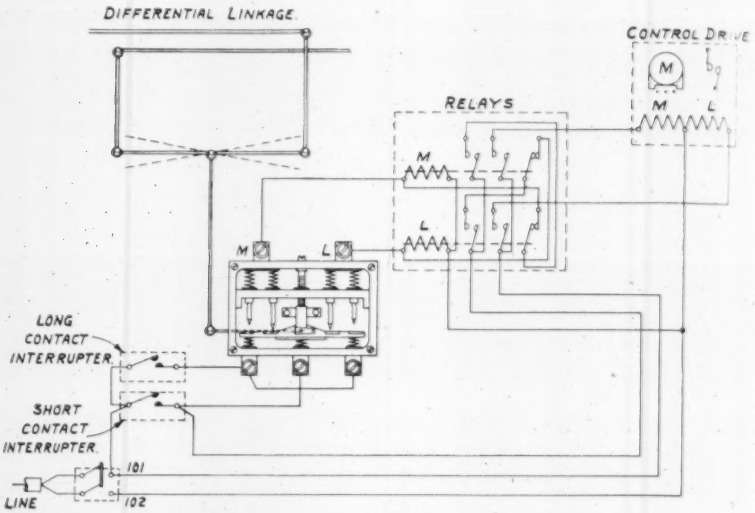



Fig. 155. Stabilizing contactor used for temperature control. Long and short contacts (for operating control drive unit illustrated in Fig. 150) are effected by the use of four contact points and a bar which is rotated about its center by the connecting linkage. The inner pair of contacts is connected in with the short contact interrupter and the outer pair of contacts is connected in with the long contact interrupter. The outer pair of contacts does not become effective until the contactor is a considerable distance out of its neutral position. The inner contacts, however, become effective soon after the contactor leaves its neutral position. Contact interrupters have been supplied so that the circuit will always be broken by the interrupter, regardless of whether or not the contact points become separated during the length of the contact itself. This is done to prevent burning of the contact points. "M" and "L" refer to the "more" or "less" clutch-operating solenoids of the drive unit. (*Bailey Meter Co.*)

As to timing, it is possible for our type of controllers to regulate the flow of medium through the valves in a certain desired time sequence. Some furnaces require the air to come on before the gas and to go off after the gas with an intermediate position where the gas is full on and the air half on. Others require the air to open ahead of the gas and to close after the gas. In chromium plating the usual practice is to open a gas valve when the temperature is high, both valves being closed when the temperature is normal. These various sequences of operation of controlling valves can be obtained with our standard type of equipment.

The Bailey Meter valve and damper operating mechanisms are representative of the modern trend. There is no space even for the briefest discussion, but Figs. 150 to 155 are self-explanatory. In connection with large installations, refer back also to the diagram of the Hagan control installation on page 454.

## Combustion Control

Engineers will recognize Figs. 150 to 153 as applying less frequently to "straight" temperature control than to combustion control. This latter subject comprises also draft control, stoker speed control, etc., and is of such importance that a later chapter is devoted entirely to combustion control instruments.

## Temperature-Time Control

A clock-revolved cam, which changes the setting point of a temperature control instrument, transforms it into a temperature-time controller. Such instruments are dealt with in a later chapter on Duration and Cycling.

# NEW INSTRUMENTS

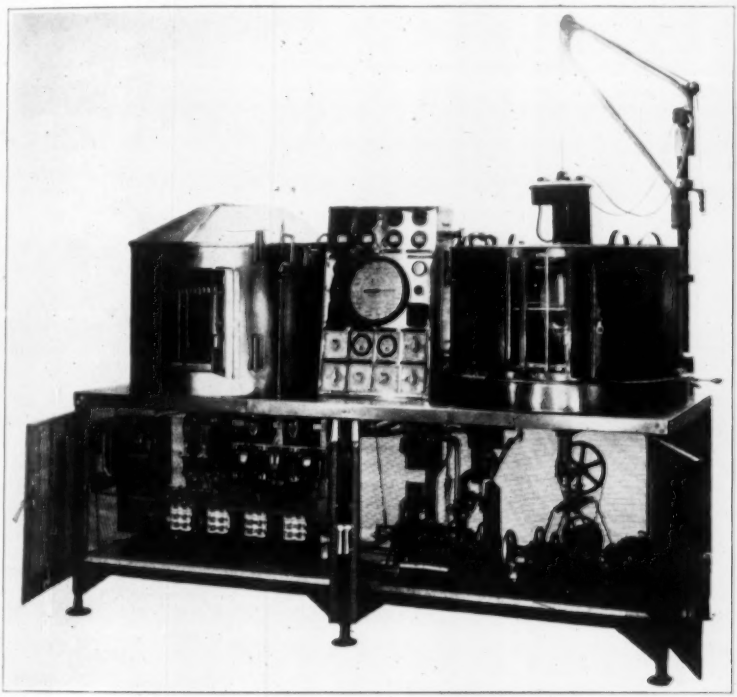
**Recently Developed by Instrument Manufacturers**

Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional Information.

## Full Automatic Weather-Ometer

*(Atlas Electric Devices Co.)*

THE Full Automatic Weather-Ometer of a special type was designed for the Naval Aircraft Factory, for the purpose of duplicating weather conditions on doped airplane muslin, and veneer wood, used in the manufacture of amphibians. Since these two-named materials must withstand summer heat at a low humidity, bright sunlight at a temperature of 90 to 120 degrees F., rain as well as high humidity found in a cloud or in the



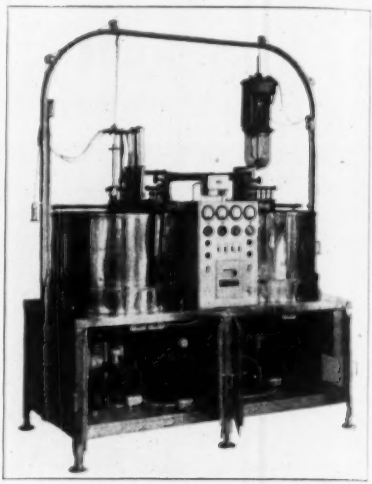
Type R. H. L. Mode 22 Weather-Ometer for Naval Aircraft Factory

sealed hull of the pontoons of the amphibians, this accelerated weathering device has been designed to bring about these varying weather conditions on a laboratory scale. The sequence of the exposure cycles are light alone, one hour, heat and light, one hour, rain and light, one hour, etc These cycles continue for twenty-two hours. The specimens are then removed from the light chamber on the right, inspected, and then placed

in the sealed high humidity chamber on the left. In this chamber a relative humidity at 100% or dew-point is maintained. Since the specimens are handled once every twenty-four hours, the removing of the specimens from light to the high humidity chamber offers an opportunity to the operator for the daily inspection of the specimen.

The specimens under test can be veneer, fabric, finished metal panels, sheet metal, and roofing material, 2 7/8 x 6 inches in size. Sixty of these specimens can be handled at once or thirty of twice the length. Metal holders are provided for textile specimens, such as airplane fabric. These holders are designed to keep the specimens under tension during the test. The ligh tused is the Standard Weather-Ometer Arc.

The Full Automatic Weather-Ometer is equipped with electric operating timing device, gas and mercury thermometers, illuminated indicators, as well as the standard equipment, such as voltage regulating switch, watt meters and volt meters.



Type H. W. F. Model DX Weather-Ometer for testing roofing material, with cycles of light, heat, rain and freezing

# Resistance Meter

*(Weston Electrical Instrument Corp.)*

This resistance meter, known as Model 506, solves resistance measurements problems in radio servicing by directly indicating resistance values from 10 to 10,000 ohms. It can also be used for making continuity tests.

It operates on two flash light cells or any other 3-volt D. C. supply. To use, it is only necessary to make a series circuit of the instrument, the 3-volt battery and the resistance to be measured.

The instrument has an etched "volt-ohm" scale and is enclosed in a 2-inch flush style case. It can be mounted on a panel or used as a portable unit by placing it in a small box together with the two flash light cells.

# New Portable Electro-Cardiograph

*(Westinghouse Electric & Mfg. Co.)*

THIS electro-cardiograph is extremely light in weight; the complete instrument is included in a compact, self-contained unit. No auxiliary equipment is necessary. The instrument requires no outside source of energy for it operates exclusively from dry batteries contained within the case. Dry battery operation has the advantages over wet batteries of light weight and absence of acid fumes. Replacement of the batteries is necessary only at long intervals.

The scheme of operation of the electro-cardiograph is as follows: the minute currents generated by the heart and flowing through the body are transmitted to the instrument through the electrodes attached to the 2 arms and the left leg. Then the heart current is amplified by tubes similar to those used in radio receivers. The amplified current causes the vibration of a tiny mirror in the galvanometer upon which is directed a beam of light. This vibrating light beam causes the impulses that are caught and recorded by a spring motor-driven camera.

Fig. 1. The new self-contained portable electro-cardiograph

The camera is arranged to receive standard 100-foot rolls of moving picture film that may or may not be daylight loading as desired. Individual records can be taken at any time without the complication of re-rolling, and the film can be cut at the completion of each record.

Although the spring motor has a governor to hold the speed within one per cent, some parts of the record may not always be within the limit. To overcome this difficulty, a time marker which operates independently of the motor, is installed to make lines 1/25 second apart on the film. This enables the operator to discard unsuitable portions, while at the same time the marks are sufficiently sharp to avoid obscuring the details of the record.

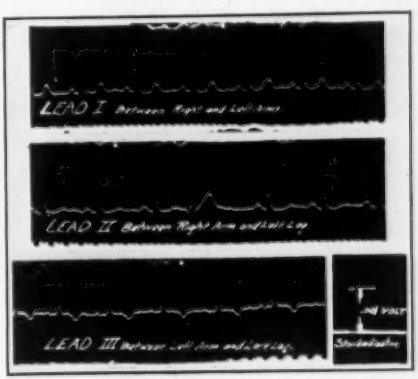



Fig. 2. A typical set of electro-cardiograms

The combined efforts of galvanometer and amplifier have been carefully calculated to prevent any distortion of the impulses. These calculations are based on the present standards of 1 inch

second film speed with 1 cm deflection millivolt, and the characteristics of the recording apparatus. The wave is correct for phase relations up to the 75th harmonic and the amplitude can be relied upon to values discernible on the film.

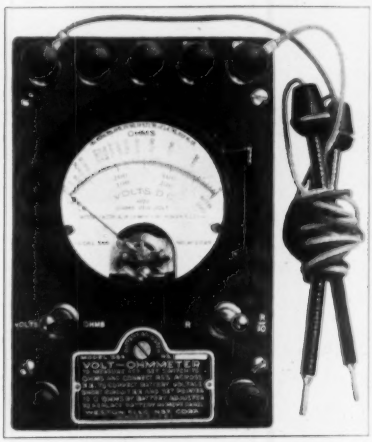
The control board has the simplest possible arrangement, making it unnecessary to go through complex adjustments to obtain satisfactory records.

The circuit used requires no compensation for body resistance or skin currents, thus allowing standardization to be made with or without the patient in the circuit. Tests show that static caused by elevators, X-ray machines, and other electrical apparatus causes no interference with the instrument's operation or records.

# New Volt-Ohmmeter

***(Weston Electrical Instrument Corp.)***

THE equipment of this meter consists of a Model 301, 3¼" diameter meter with ranges of 3, 30, 300 and 600 volts and 2 resistance ranges 0-10,000 and 0-100,000 ohms. These 6 ranges are brought out to binding posts as shown in the illustration. Two toggle switches serve to connect the meter in circuit. All voltage ranges have a resistance of 1000 ohms per volt. A pair of 30" cables with long test prods is provided with each instrument.




The overall dimensions are 5½" x 3⅝" x 2⅛" deep (excluding binding posts) and the weight is 2.3 pounds including the self-contained "C" Battery.

*Voltage Measurements*—To make voltage measurements, connect one of the test leads to the "—" Binding Post above the meter and the other to one of the posts marked 3 V., 30 V., 300 V. or 600 V. depending on the range desired. Set the toggle switch at the left to "Volts." The instrument is then available for use as a voltmeter.

*Resistance Measurements* — To make resistance measurements set toggle switch at the left to "Ohms" and the toggle switch at the right to R or R/10 depending on whether the use of the 100,000 ohm scale or 10,000 ohm scale is desired. Then connect the test leads to Binding Post X-X. To compensate for changes in potential of the self-contained 4½ volt "C" Battery, short circuit binding post X-X and adjust the pointer of the meter to the zero ohm position by turning the voltage adjuster located at the top of the name plate.

*Continuity Tests*—When checking continuity of circuit follow the same procedure as outlined for Resistance Measurements. The sensitivity of the meter can be changed to either 1 or 10 milliamperes by operating the toggle switch on the right side of the instrument. This simplifies checking up trouble in high or low resistance circuits.

# Automatic Ratio Control for Gases & Liquids

*(Bailey Meter Company)*

THIS control finds many applications in steel mills, oil refineries and process industries where mixtures of fluids must be definitely proportioned in a given ratio to secure the best results.

Air and fuel for combustion in industrial furnaces may be automatically proportioned by this control so as to secure maximum fuel economy. A control of this kind can be applied to both liquid and gaseous fuels or to a combination of the two in such a way as to insure the highest combustion efficiency consistent with economical operation. Mixing of two or more gases or liquids to form a low cost fuel can also be accomplished by this control.

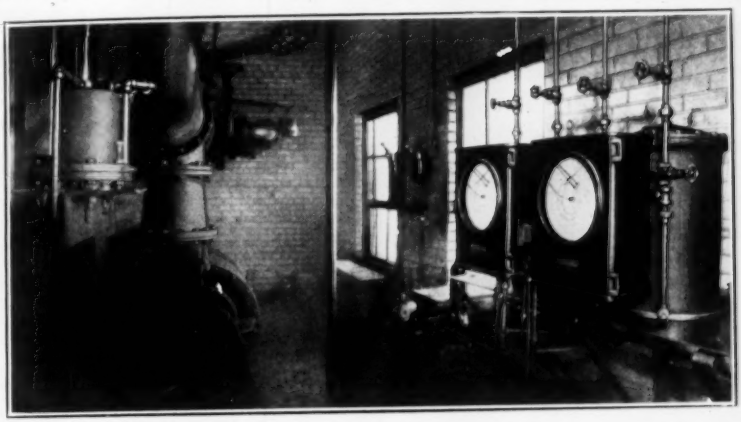


Fig. 1

Fig. 1 shows an installation of the ratio control in a steel mill, where it is used to automatically proportion blast furnace gas and coke oven gas. Blast furnace gas in itself is too lean and low in heating value to make a satisfactory fuel. Coke oven gas is too valuable to use by itself as a fuel but a mixture of two parts blast furnace gas to one part coke oven gas forms an ideal low cost fuel. This mixture is maintained by the ratio control.

As will be noted from Fig. 2, the control is operated by hydraulic pressure. Any change in the rate of flow in the coke oven gas line is immediately reflected by the Bailey Gas Meter connected to that line. The recording mechanism of this meter is connected through a system of linkage to a pilot valve, stabilizer and Bailey Gas Meter, which meter is in turn connected to the blast furnace gas line. If the flow of coke oven gas increases, the linkage moves so as to raise the pilot valve, allowing oil pressure to be applied to the "more" side of the power cylinder. At the same time, this movement opens the "less" side of the power cylinder to drain. The stabilizer tends to counteract the impulse given by the coke oven gas meter. This counteracting effect of the stabilizer is secured by connecting the "more" oil line to the upper chamber of the stabilizer and

the "less" oil line to the lower chamber of the stabilizer. As pressure is applied to the "more" oil line and the "less" side is open to drain, the stabilizer piston moves downward and tends to return the pilot valve to a neutral position which in turn tends to equalize the pressures on either side of the stabilizer, causing it also to take a neutral position.

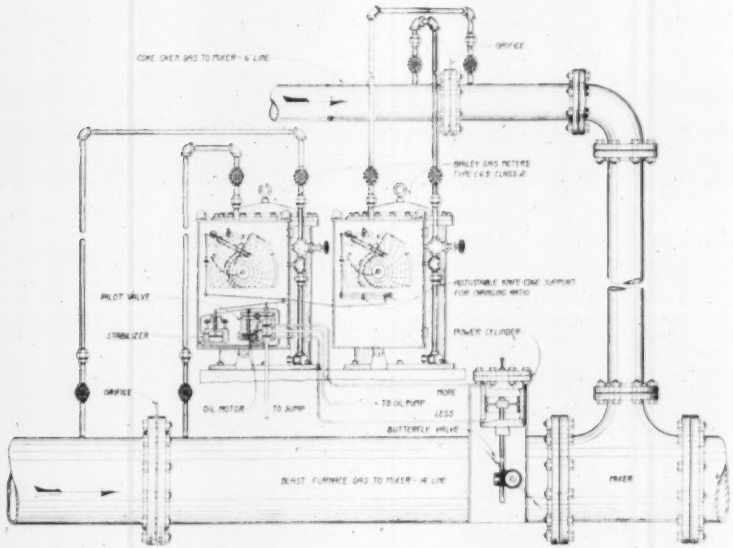



Fig 2

The stabilizer permits of a quick acting control which does not over travel or hunt.

Any desired ratio between the two component parts of a mixture can be secured by selecting the proper ratios for the meter orifices. A further adjustment or change of ratio can be had by use of the ratio changing device which is simply a movable pivot supporting the linkage in the right hand meter casing.

THE specifying of instruments and devices for measurement, testing and control starts with engineers, works managers, research engineers, test engineers, routine laboratories, consulting engineers, etc.

**INSTRUMENTS**

can assist you in locating both buyer and seller.

# New Type of Remote Control

*R. D. Bean**

IMPROVEMENTS in plant design over the past few years have been aided in large measure by increased facilities for control of various parts of the operation. Instruments of all kinds have been developed for observing and recording operating conditions, and in many cases instruments are equipped to control automatically a pre-determined condition, or to perform a limiting function in the event that certain conditions develop.

The chief drawback with automatic equipment, however, always has been its lack of the human factor—judgment. Manual operation in many cases of power plant and process controls is still essential because of the need of human interpretation in the use of such controls.

The design of almost all power plants, or processes, involves a system of piping and indications of the conditions throughout the system are registered or indicated by pressure gages, pyrometers or various recording instruments. This part of the equipment has been developed to a high degree and their centralization has become standard practice.

Where a distant valve must be opened or closed to the precise degree required to make a desired correction, the problem is complicated by the need of actual control of the valve in question. It is usual for the operator to note the conditions existing in the system and then issue orders to have the necessary adjustments made to effect the correction required. The change required by the operator is thus made through a second operator and the extent of the change must be described by the first and interpreted by the second. If the correction, when made, is too great or too small, the effect will be detrimental to the performance of the plant or service.

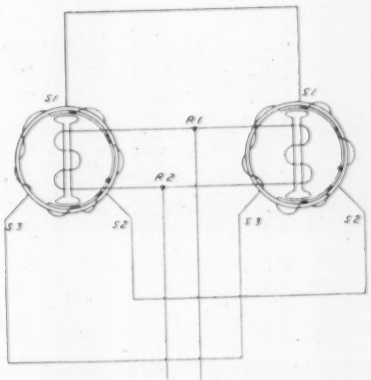



Fig. 1

The ideal arrangement of centralized control would be to place in the hands of the operator in charge of the control panel a means of making his own corrections, for he is in a better position to judge than another operator who merely receives an order to make a change. There are many controls which are preferably governed by manual operation and it is evident that some system of remote manual control, from the board, is necessary in the progress toward centralizing the responsibility for the entire operation under one mind.

Remote valve controls have been used in the past with mechanical connections, but as they are limited in their ability to produce motion at a distance, the control must be made possible in many cases by diverting pipe lines to within reach of the control board, or by placing the control board in a favorable place to make the arrangement possible. Electrical and hydraulic devices used heretofore have not been particularly well suited for adjustment.

The ideal control is evidently one in which the receiving mechanism will follow accurately the motion of the transmitter and, in addition, it is desirable to have the resistance to motion felt on the transmitting end, in order to be certain that the necessary change is being made and no damage done.

Bearing in mind the foregoing, a remote control device has been developed, using self-synchronizing alternating current motors which have the property of remaining accurately in phase. When connected and energized, any power applied to one motor will be transmitted to the other with comparatively little distortion and their action can not only be used to transmit indications but also to transmit power necessary to effect control. It is evident that the application of such a principle is a wide one and that the use of such mechanism not only permits greater ease and simplicity in control from a central point but permits a great deal more latitude in the design of piping and equipment, since the control of certain important valves can be effected without respect to their position in the system.

The motors, known as Selsyn Motors, have been used heretofore in connection with fire control on battleships. Diagram (Fig. 1) shows the connections for the electric circuit of the transmitting and receiving motors. The motors, which are entirely encased, are further gas

* Manager of Engineering Development, Brown Instrument Company

proofed by suitable covers, and the rotating shaft, mounted on ball bearings, makes possible its use in any position. They are made in three sizes depending on the power required and whether the units are required for transmission of power or indicating mechanism.

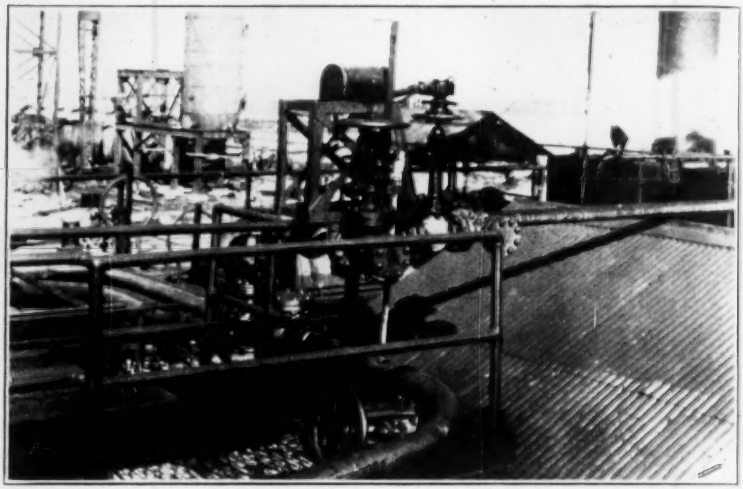


Fig. 2

Figure (2) shows the arrangement of a transmitting and receiving mechanism as applied to a valve, and further illustrated in the accompanying photographs. The transmitting mechanism comprises a wheel which rotates the transmitting motor through a gearing and through which the control is effected. The rotating of the transmitting motor causes the rotation of the receiving motor, the motion of which is transmitted through a gearing to a shaft and thence to a worm gear which in turn is connected to a wheel on the valve stem. The worm gear mechanism is connected to the valve wheel by means of a clutch, half of which is clamped permanently to the spokes of the valve wheel, the other half being directly connected with the worm mechanism. A quick detachable clutch is inserted between the wheel and the worm case so that the mechanism can be disconnected quickly and at will. It will be noted that the drive shaft from the receiving motor is flexible and that the mechanism can thus be applied to a wheel which is solidly mounted on the valve stem and which will rise and fall as the setting is changed. In addition to this, the worm gear is hollow and in the event that the mechanism is applied to a rising stem valve, the stem can pass freely through the center of the worm.

The transmitting unit is made up in small panels roughly 30" x 16" and can be bolted through control panels or assembled in batteries. A pointer or indicator is connected with the motion of the transmitter wheel to denote the amount the system is turned and a pilot light is incorporated in the unit to indicate when the circuits are energized.

The receiving mechanism can be applied to any type of valve or to effect any rotary motion desired. The power transmitted to the receiving mechanism is only that which is impressed on the transmitting wheel. Thus the resistance to motion can be gaged and the actual amount of correction observed on the wheel in the same manner as it would be observed in turning the valve itself. There is, of course, some loss in friction but this is comparatively small and ample power is provided to start the valve from full closed jammed position when necessary.

The motors themselves, which can be likened to rotary solenoids, have of course, a limited amount of torque which they can transmit without having the phase broken down. This torque can be amplified however, by merely gearing up the transmitting motor and gearing down the receiving motor. Thus the power is transmitted at low torque and high speed and the extent to which the motors are out of phase becomes relatively unimportant, since this amount, which may aggregate 5 or 10°, is reduced in proportion to the gear ratio. Thus, with a gearing of 100 to 1 on the transmitter and receiver, the valve wheel would move the same number of turns as the transmitting wheel; one turn of the transmitting wheel would cause 100 turns of the transmitting motor and correspondingly 100 turns of the receiving motor, also geared down 100 to 1, or one turn on the valve wheel. Furthermore, the extent

to which the motors were out of phase during this process would be 100 times greater than the extent to which the transmitting wheel and valve wheel would be out of phase. If we assume a 10° change in phase of the motor shafts, the transmitting motor and valve wheel would be only 1/10° out of phase which for all practical purposes is negligible. The mechanisms are made usually to transmit from 150 to 200 foot-lbs., which appears to be ample to turn any valve mechanism. They also can be made to operate in any ratio desired to obtain close control and it would be possible to have, by changing the gear ratio, four turns of the transmitting wheel to one turn of the valve in the event a close regulation is desired or a heavy valve is to be turned.

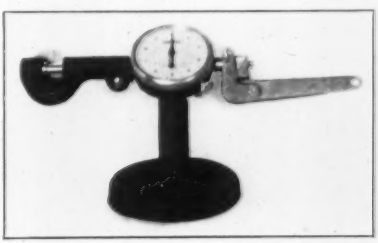
It will be evident that applications of remote control of this type are almost unlimited. It is most usefully applied where controls are comparatively inaccessible and would ordinarily require mechanical facilities for access and additional labor to operate.

From the point of view of design, the remote control enables considerable saving in piping and in many cases removes the necessity of platforms and structural work to operate certain valves. It furthermore gives greater liberty in the design of the units as it does not force the position of the control panel in any particular locality but enables it to be placed where it is in the least danger from fire hazard and away from dust and dirt caused by cleaning. The mechanism is safeguarded by the fact that the motors do not rotate when energized by the current and respond only to hand motion. In the event the current fails, the valve would remain in whatever setting it happens to be placed; but, as noted previously, it can always be operated by hand and released from the control system if necessary. There is no danger of overloading or of breakage since the power transmitted is merely that applied to the transmitting wheel. Any resistance or reaction on the receiving end is of course felt on the transmitter, so that, if the valve were jammed or its stuffing box too tight, this resistance would be felt in transmitting the motion. In other words, the man operating the remote control can actually feel what he is doing and obtain an immediate and natural reaction to any adjustment he makes. The advantages of this feature are obvious.

# Small Wire Gage

## (*Federal Products Corporation*)

THIS gage is for measuring all kinds of small wire to tolerances of .0001". It is a bench type gage and has a lever arrangement that can be operated either by hand or by foot by simply attaching a small wire or string through the hole at the end of the lever and dropping it through the bench to a foot pedal.



The indicator is graduated in .0001" and each numeral on the dial represents .001" and the indicator can be swiveled on the bracket so as to get same in direct vision with the operator depending upon his position while taking readings.

The small metal piece shown on the back of the anvils is a guide so that when the wire is drawn through it will always be in the center of the anvils.

The method of operation is for the operator to pull down on the lever which opens the anvils, draw his wire through and take readings at any point on same that he may desire.

The frame and the anvil carrying block are hyloed, finished in black. All other exposed parts, including the rack of the indicator, are chromium plated.

# New Instrument for Rapid Moisture-Content Determinations in Wood

*C. G. Suits*[1] *& M. E. Dunlap*[2]

FOR several years the Forest Products Laboratory has been working toward the development of rapid moisture indicators for wood, in the hope of devising a method that would meet the general needs of the wood-working industry more satisfactorily than the present oven-drying process. When it is carried out properly, the oven-drying process is time-consuming and wasteful. This phase of the situation alone led several other investigators to work on the problem, with a resulting contribution of practical apparatus from some of them.

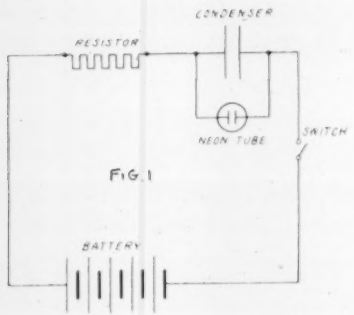



FIG. 1

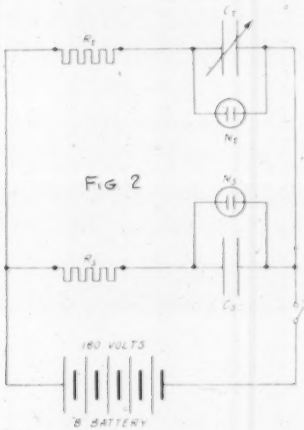



FIG. 2

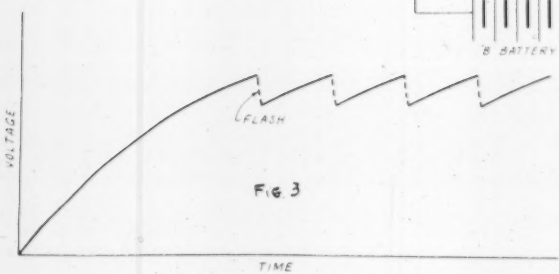



FIG. 3

Fig. 1. The Fundamental Simple Circuit for the "Blinker."
Fig. 2. The Fundamental Branched Circuit for the "Blinker."
Fig. 3. An Elementary Flash Diagram.

The new instrument depends upon a simple circuit that operates on 180 volts direct current; as shown in Fig. 1, the circuit consists of a battery, a resistance unit, a condenser, a neon tube, and a switch. When the circuit is closed the condenser is charged through the resistor, which regulates the current flow, permitting a gradual building up of the voltage across the condenser and the tube in parallel with it. Ionization in the tube

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[2]Senior Engineer, Forest Products Laboratory, Forest Service, U. S. Department of Agriculture.

occurs at a definite potential. The ionization point is indicated by a flash through the tube, which reduces somewhat the voltage across it. When the condenser charge again builds up another flash takes place, as represented diagrammatically in Fig. 3. If the resistance is increased the period between the flashes will be increased, and if it is lowered the period will become shorter. Thus the approximate value of the moisture content of a piece of wood may be obtained by using a sample of the wood as the resistor and counting the number of flashes in a unit of time; such a determination is possible because of the relationship between the moisture content and the electrical resistance of wood.

Fig. 1 outlines the fundamental circuit. An arrangement for moisture-content determination is given in Fig. 2, which shows a two-branch circuit energized by a single battery. For one branch a standard resistor $R_s$, a condenser $C_s$, and a neon tube $N_s$ are selected so that the neon tube will indicate at a rate of approximately 1 flash a second. For this purpose the resistor may be approximately 4 megohms, and the condenser about $\frac{1}{4}$ microfarad; these values will vary somewhat with the properties of the neon tube used. If a larger flash is desired a larger condenser may be chosen and a somewhat lower resistance substituted.

The instrument is so arranged that, when a sample of wood is introduced into the other branch of the circuit, any one of a number of condensers varying in capacitance from 0.000044 microfarad to about 5 or 6 microfarads may be switched into the circuit. The frequency of flashes of the test lamp, $N_t$, can thus be adjusted to approximate that of the standard lamp, $N_s$. The values of these condensers, instead of being expressed in microfarads, may be expressed in moisture content, so as to give direct readings.

Using the branched circuit as a basis two instruments have been designed, one of which is intended for the measurement of moisture content between the limits of 8% and 26%, at intervals of 1%, while the other is intended for sorting lumber for moisture content. These instruments are illustrated in Figs. 4 and 5, respectively.

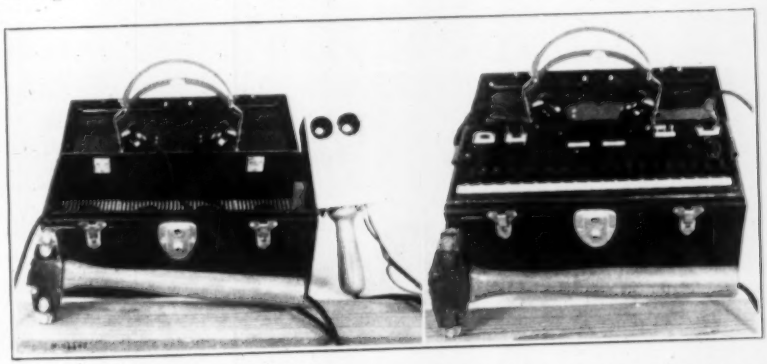


Fig. 4. The "Blinker" Instrument for Measuring Moisture-content Values between 8 and 26%.

Fig. 5. The "Blinker" Lumber Sorter Ready for Use.

Fig. 6 presents the wiring diagram of the moisture measurer. The switches $S_7$ to $S_{26}$ are shown open only because the diagram is easier to read that way. In actual use all these switches are normally closed, all condensers in consequence are initially in circuit, and the determination is made by opening switches in turn, thus cutting out all condensers to the

right of the open switch, until the test neon lamp, $N_t$, flashes at the same rate as the standard lamp, $N_s$. When this condition of equilibrium has been established, the number of the open switch gives the moisture content desired. The "wood sample" that is represented in a simple manner in the diagram is of course the wood into which the hammer points are driven.

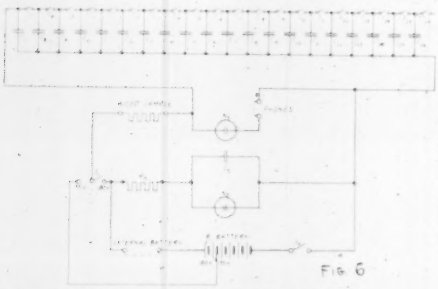


Fig. 6

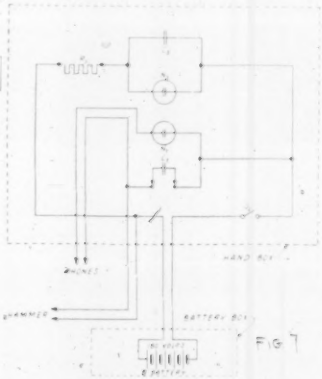


Fig. 7

Fig. 6. Wiring Diagram for the "Blinker" Moisture Measurer

Fig. 7. Wiring Diagram for the "Blinker" Lumber Sorter

The lumber sorter is designed merely for determining whether the board tested is wetter or drier than some designated moisture content. Fig. 7 gives the wiring diagram of the sorter. The only essential difference between the circuits of the measurer and of the sorter is in the condensers. Instead of the many condensers of the measurer, all of which are constantly available, the sorter has only one test condenser, $C_t$, in circuit at any one time. This condenser is selected from a set to make the sorter indicate equilibrium at any value of moisture content that may be desired, and is plugged into circuit to remain until the sorting job in hand has been completed. If the test lamp flashes faster than the standard lamp, the moisture content of the sample is higher than the limit for which the sorter is adjusted, if it flashes at the same speed the moisture content is equal to the limit, and if it flashes more slowly the moisture content is below the limit.

Convenience and speed of operation were primary considerations in the design of the lumber sorter. The sorting may be done with the use of head phones or by visual observation of the flashing of the two lamps, as the inspector prefers. The lamp bulbs are below the two circular openings shown in Figs. 4 and 5.

## Correction

The corrections noted below should be made in the description of the A. P. C. Opacimeter, which appeared on pages 401 and 402 of the June issue.

4th paragraph, 1st line—change "—at the right of—" to "—above—"

4th paragraph, 3rd line—change "—switch above the—" to "—switch to the left of the—"

6th paragraph, 1st line—change "—in the upper left hand—" to "—in the lower left hand—"

6th paragraph, 3rd line—change "—in the upper right hand corner—" to "—in the upper left hand corner—"

7th paragraph, 5th line—change "—capacity—" to "—opacity—"

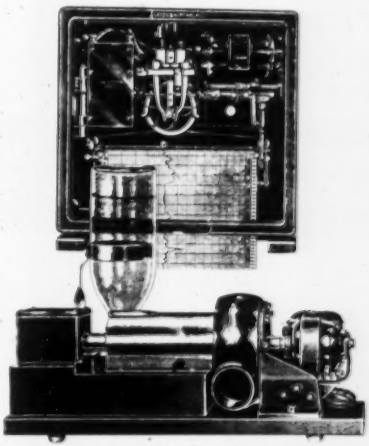
8th paragraph, 6th line—change "—capacity—" to "—opacity—"

# Relative Humidity Recorder

*(Leeds & Northrup Company)*

THE humidity recorder here described continuously records the relative humidity of air. As in the ordinary psychrometer, the basis of the measurement is the difference in temperature of wet and dry bulb thermometers in a current of the air. The ordinary apparatus, however, shows only the wet and dry bulb temperatures, and the observer finds the humidity corresponding to them from a psychrometric table or chart. The distinct advantage of this humidity recorder is that it registers the relative humidity directly.

The complete equipment comprises two separate electrical units, one designated the wet and dry bulb apparatus and the other the recorder. These may be a considerable distance apart. They are connected together by appropriate electrical conductors, the length of which has no effect on the operation of the equipment.



This device comprises two similar electrical resistance thermometers mounted in a tunnel through which a stream of the air under test is drawn by a small exhaust fan. Provision is made for keeping the surface of one of the thermometers wet.

The temperature-sensitive element of each thermometer is a flat coil of pure nickel wire wound on a mica strip and laid between two similar strips to insulate it from the metal case which fits it closely. The two coils are very carefully matched to have the same electrical resistance at the same temperature, and the same change in resistance with a given change in temperature. The case is a sheath of thin metal, and is pressed firmly against the mica insulating strips, making the thermometer very rapid in response to temperature change. The case of the dry bulb thermometer is of a copper-nickel alloy; that of the wet bulb thermometer is of gold, to resist corrosion. In each thermometer the air inclosed with the coil is perfectly dry, and the case is water-tight, the connecting leads being brought out through a glass plug sealed in one end of the case and inclosed in a protective covering that forms the head of the thermometer. To support the thermometers, the heads are fastened in the removable side of a moisture-proof junction box, in which the terminals of the connections to the thermometer windings are soldered to the conductors which connect them to the recorder.

The case of the wet bulb is fitted with a wick which extends into a shallow tank of water, and by capillary action keeps the surface of the bulb saturated throughout its entire length. The wick is made of a small square of absorbent cloth by hemming one edge to form a sleeve that fits the thermometer case closely when wet. If is freed from grease or oil by boiling it in a mild caustic solution, then rinsed in clean water and dried. It is then inclosed in an envelope to protect it from contamination until it is used. In ordinary circumstances the wick is changed each day, but in unusually favorable circumstances it may be used longer.

The thermometers are mounted so that the water in the wick has to rise only a short distance. The surface of the water in the tank is kept at a given level within small limits of fluctuation by a reserve supply in an inverted bottle. The bottle is refilled once a week.

A tunnel for a stream of the air to be tested is formed by partly inclosing the space over the tank. The nickel-alloy sheet metal cover is easily removable for access to the thermometers, for replacing the wick. The tunnel is divided into two passages by a partition between the two thermometers. A small exhaust fan keeps the air stream flowing through the tunnel at a velocity sufficient for proper evaporation from the wet bulb in any conditions of air temperature and humidity. The fan motor can be furnished to operate on any lighting circuit.

Each thermometer is connected to the recorder by a cable of four conductors. Two conductors in the cable are connected with the terminals of the resistance thermometer coil, and the other two are connected to the terminals of a compensating loop circuit within the thermometer case. With this type of connection the length and therefore the resistance of the conductors, and any change in resistance with change in temperature, have no influence

on the record. Rubber-covered cable has been found satisfactory for use even under conditions of extremely high humidity.

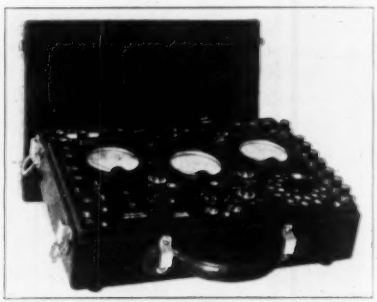
A standard L & N recorder for use with resistance thermometers has a special combination circuit, for recording relative humidity directly, within the limits of 20 and 100%. Since the method involves evaporation of water from the wet bulb, the lower limit of air temperature at which the equipment will record humidity correctly is fixed by the freezing point of water. The upper limit is about 175°F (80°C) dry bulb temperature. Within this range the recorder is sensitive to a change of about 0.5% relative humidity. The limit of error in its performance is within 1.5% relative humidity.

The recorder draws a continuous curve of relative humidity on a chart approximately 10 inches wide, with a scale reading directly in relative humidity, from 20 to 100%. The chart is moved forward at a constant rate of $1\frac{3}{8}$ inches per hour, owing to a synchronous motor drive. Time intervals in hours are printed on one edge of the chart. Power for the mechanism which keeps the chart in motion, and which also automatically balances the recorder measuring circuit and moves the pen, is supplied by a 110 volt 60 cycle synchronous motor. The action of the balancing mechanism is directed by the recorder galvanometer. This unit is not calibrated, and in case of accident it can be replaced by a similar unit without affecting the accuracy of the record.

# Radio Set Tester and Tube Checker

*(Weston Electrical Instrument Corp.)*

THE tremendous strides in the development of radio receivers have placed them far beyond the scope of home self servicing facilities. Because of these rapid advances, receivers today are more intricate than ever before. Consequently when troubles occur they require the services of competent trained men—men who know radio and who are equipped with reliable and adequate test equipment.



Model 565 is a complete set tester embodying features such as an oscillator, a double range direct reading ohmmeter and a tube checker for A.C. and D.C., rectifier type and pentode tubes. The entire set is completely self-contained and housed in a compact carrying case with a removable snap-on cover.

The instrument equipment consists of three $3\frac{1}{4}$" diameter panel instruments, an 8 range A.C. instrument for 1000, 200, 16, 8, 4 volts, 4 amperes and 100/20 milliamperes, a 13 range D.C. instrument for 1000, 250, 100, 50, 25, 10, 5 volts, 0-100,000/0-10,000 ohms and 100/25/2.5/1 milliamperes and a double range D.C. instrument for 100/20 milliamperes. Shunts may be obtained to increase the 20 MA range of the D.C. Milliammeter to 2 or 10 amperes.

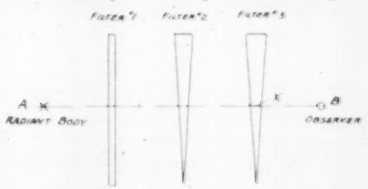
The various ranges of the D. C. Volt-Ohm-Milliammeter are controlled by a 23 point bi-polar switch with colored index markings for rapid classification of readings. The ranges of the A.C. meter are controlled by a 9 point Bi-Polar Switch. A toggle switch is used to change the ranges of the D.C. Milliammeter. Three tube sockets are provided on the set, a UX, a UY and an oscillator tube socket. Adapters may be obtained for large or small UV tubes.

# Pyrovisor—A New Optical Pyrometer

*(American Demag Corp.)*

THE principle of this color pyrometer is the comparison of the intensity of two monochromatic radiations. Such a comparison of two intensities without a known light source is possible due to the physiological property of the eye to perceive two different colors, concentrated in the same spot, as a third mixed color distinctly different from the two component colors, provided both colors are equal or practically equal in their individual physiological reactions.

If the light of a radiant body of constant temperature passes through a filter which allows only the passage of two colors, far apart in the spectrum, with the wave lengths L-1 and L-2, then the eye perceives a light or a color mixture, which, according to the intensity ratio of the two colors, appears either as pure color L-1, or as a mixed color, or as pure color L-2. If the filter is of such a nature that it passes, not the pure color L-1 or L-2, but only the mixed color and if the temperature of the radiant body changes, then the ratio of L-1-L-2 changes also, with the result that the filter no longer shows the mixed color because now one of the two colors predominates. It is possible to make a second filter which is just right for this new color ratio and which allows only the passage of the new mixed color. This may be continued until a large number of filters has been made, each of which gives only the true mixed color for a given ratio of L-1-L-2 and each of which represents therefore a definite temperature. For correct, rapid and convenient measurements, it is of course necessary to have a filter which gradually changes the amount of the two colors passing through it in a ratio which is different for each of them. For the color pyrometer the two colors green and red have been selected.




The light filter of the color pyrometer works in accordance with the following principle: The light from a radiant body "A" passes successively through filters 1, 2 and 3 to the eye of observer "B."

Filter 1 absorbs all light with the exception of green and red. Filters 2 and 3 are geometrically identical but wedge shaped. Filter 2 absorbs the red light in an increasing degree according to the increasing thickness of the wedge but passes all green light, while filter 3 on the other hand passes the red light but absorbs the green light in an increasing degree according to the increasing thickness of the wedge. The observer, looking through different parts of the filter aggregate perceives a mixture of both colors, which mixture is composed of different quantities of the red and green light at every spot of the filter. The true mixed color, neither green nor red, is, however, visible and recognizable only in one definite spot of the filter.

Assuming green is absorbed to a greater degree than the red with increasing thickness of the wedge-shaped filter and that at point "X" of the filter a definite red-green ratio of the radiant body will give the true

mixed color, then on the right of "X," the filter will appear red since there more green is absorbed, while on the left of "X" the filter will appear green since there is less red but more green passing through the filter. Should now the temperature of the radiant body increase and with it the green-red ratio of its radiation, then due to the more intense green radiation of the body the spot where the true mixed color appears is changed towards the right end of the filter, since in order to get the equilibrium between the two colors the increased green radiation must be overcome by absorbing more of the green color. The spot where the two colors show the true mixed color is, therefore, dependent on the green-red ratio in the radiation of the glowing body and it is on the determination or finding of the spot where both these two colors mix and where neither green nor red is visible, that the temperature measurement by means of the color pyrometer depends.

The accuracy of the temperature measurement with such a color pyrometer depends first on how much the position of the spot, where the two colors mix, changes with every change in the temperature of the glowing body, and second on the individual ability of the observer to determine the true mixed color. The change in the position of this spot in the filter due to the change in the temperature of the radiant body is the greater the farther the wave lengths of the two colors are apart from each other in the spectrum. Generally speaking the most suitable colors are those which are complementary colors because they give a white mixed color which may be determined with greater ease and certainly from the two component colors than any other mixed color. For the color pyrometer the two colors green and red were selected, of which green lies in the area of great sensitivity.

The color filter of the pyrometer consists of a mixture of organic color substances with the property to pass almost true monochromatic green and red only and to absorb with increasing concentration more green than red. Dry gelatine wedges saturated with this color substance are placed between two special glass strips and the pyrometer is calibrated against a black body having a definite known temperature. The shape of the pyrometer is that of a slide-rule with the color glass held in a frame on which the temperature is engraved. To facilitate the finding of the spot where both colors mix and appear white, a slide with a round observation hole is mounted on the frame. The observer focuses the glowing body through the observation hole in the slide, held in his right hand, and moves with his left hand the frame with the color glass until he finds the spot where neither green nor red is distinctly visible, but where both colors mix and show a white or whitish-yellow color.

The accuracy of the temperature measurements depends to a great extent upon careful avoidance of fatiguing the eye for one of the two colors. It is therefore necessary not to look for too long a time at the glowing body through the pyrometer where either the green or red color predominates. It is, however, easy to overcome this difficulty by first finding with one eye the approximate spot where the colors mix and then by switching over to the other eye to determine accurately the spot where the true mixed color appears. The accuracy of the color pyrometer readings is about 1%, which accuracy, however, can be increased after several days practice with the instrument.

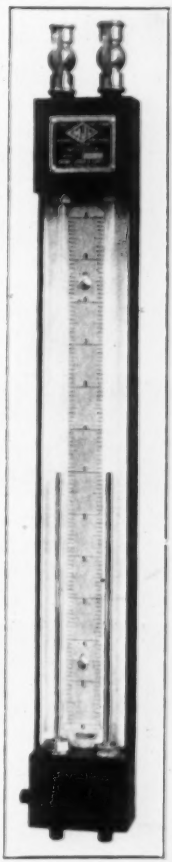
The color pyrometer does not require any auxiliary apparatus: batteries, lamps, etc., and can be used indefinitely without any calibration. Tempera-

ture readings are made in a very short time and it is possible to measure the temperature of the largest as well as the smallest bodies. Hot spots on ingots, billets, etc., are easily determined with the Pyrovisor. The temperature can be taken at a considerable distance from the hot body since the reading will not be affected by smoke or other light dimmers. The light weight of the Pyrovisor, which is only five ounces, makes it the most convenient high temperature pyrometer which has so far been offered to the industry.

# New High-Pressure Type MJL Manometer

*(Morey & Jones, Ltd.)*

THIS manometer has been developed to include several desirable features for permanent as well as portable, test instruments. The standard design, while primarily intended for use as a flow indicator, for high-pressure work, has been built for pressures up to 300 lbs. gage; and is useful in all types of test work where manometers are employed. With but slight changes in glass packing arrangement, etc., it is built for use on pressures to 2500 lbs. or more.



It is a two-glass-leg type instrument of especially compact and neat appearance, having a check feature at the top in both "legs," to prevent loss of mercury, due to pulsations or over-capacity flow. Being built in three standard lengths, 6", 12" and 18" scale lengths, it fills all usual conditions for test and permanent work. This manometer is especially adaptable for use on water filters and softeners, since with the two indicating glasses, it will show normal flow rate in one direction, and also the "back-wash" rate, when flow is in opposite direction. The non-blow-over of mercury feature, is also most needed for this particular application.

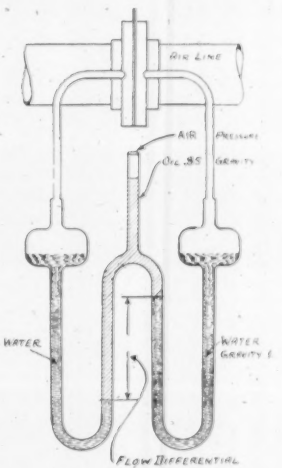
Solid blocks of steel are used at top and bottom with an aluminum housing for glass, and aluminum scale plates. Latter can be marked in standard inches of water or mercury, or "direct-reading" in gals./min., per hour, etc. Entire instrument is chromium plated to withstand outdoor applications. Packing arrangement around the two glass "legs" are simple, but particularly effective for high-pressure applications. One special feature of this manometer is that the high-pressure glass tubing used, is specially selected so that no errors are introduced by varying inside diameters—either of one glass from the other, or from top to bottom of the same piece of tubing. This point being particularly important in test instruments of this nature.

# New Manometer Type Instrument Indicates Both Pressure and Flow at Same Time

(*Meriam Company*)

THIS type is expected to largely supersede the previous combination type for the same purpose, and which provided a set of two-way cocks by means of which the U-tube manometer could be either connected to the line so as to measure the differential pressure across the two sides of an orifice of known size inserted in the pipe line—thus measuring the rate of flow—or could be connected between the pipe line and the atmosphere—thus showing the line pressure above atmospheric. The change could be made in a few seconds, but it was not possible to read both simultaneously.

The new type is of entirely different construction, and two different colored non-mixing liquids are used instead of only one. In most cases, red oil and water are employed; but other heavier or lighter liquids may be used according to the pressures and flows to be dealt with. The design of the new tube, as shown in the accompanying sketch resembles a "W" instead of a plain "U." The two outer ends of the "W" terminate in bulbs having openings which are connected to the pipe line in the same way as the ends of the U-tube of an ordinary flow meter—on either side of the orifice disc of known size which produces the differential pressure corresponding to the rate of flow. From the middle point of the "W" a riser tube is connected. This riser tube is of a height proportionate to the line pressure to be measured and to the liquid used.




To operate the instrument, the heavier liquid is first poured into each U-tube so as to occupy approximately one-half of the height of same. The lighter liquid is then poured into the riser rube which is open to the atmosphere), so as to act as a seal. As this addition will make the levels of the heavier liquid in the U-tubes unequal, sufficient of the lighter liquid is then added at the bulb ends to counterbalance and correct this. The instrument is then installed on the pipe line.

The action is as follows. The total pipe line pressure above atmospheric being connected to both ends of the "W," the levels of the heavier liquid on the two inner U-arms are forced upwards, thus raising the level of the lighter liquid in the open riser tube to a point corresponding to the line pressure.

The differential pressure due to the orifice or pitot and the rate of flow, on the other hand, is not affected by this, and it is indicated independently by the *difference* in level between the heavier liquid in the two inner arms. It is obvious that neither action affects the accuracy of the other in any way.

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**RHEOSTAT.** Bulletin 1265 briefly describes and gives data on a new Jagabi rheostat. James G. Biddle, 1211 Arch Street, Philadelphia, Pa.

**INDUSTRIAL INSTRUMENTS.** General catalogue illustrating instruments for measuring: temperature, pressure, volume, etc. This is printed in German. J. C. Eckardt A. G., Stuttgart-Cannstadt, Germany.

**BENDING STRENGTH TESTER.** 307 describes and illustrates the Naumann-Schopper bending Tester for cardboard, etc. Foreign Paper Mills, Inc., 72 Duane Street, Pittsburgh, Pa.

**METAL TESTING INSTRUMENTS.** 88-page catalogue describing a complete line of physical testing apparatus for material testing. H. Z. Schniewind, 72 Duane Street, New York, N. Y.

**FLOW GAGE.** Leaflet describes the Collins flow gage, a combination of impact tube and water-air manometer. Arthur L. Collins, 7 Front Street, San Francisco, Cal.

**WATER LEVEL INDICATORS.** Leaflet describes the installation of Stevens long distance water level indicators on the locks of the Welland ship canal. Leupold, Volpel & Company, 267 Washington Street, Portland, Oregon.

**GENERAL RADIO EXPERIMENTER.** The June 1930 issue of the Experimenter is an anniversary issue commemoratmg the 15th anniversary of the General Radio Co. The issue is devoted to a description of the plant, the officers of the company and the engineering staff. General Radio Co., Cambridge A, Mass.

**GET IT ON PAPER.** This is the title of a folder 8½ x 11 illustrating the importance of keeping records of the flow of liquids and gases, etc. Brown Instrument Company, 4482 Wayne Ave., Philadelphia, Pa.

**COUNTER CONTROLLERS.** A leaflet illustrating a new counter controller. Adde & Company, Portland, Maine.

**IMMERSION PYROMETERS.** Leaflet describes immersion pyrometers for molten brass, bronze and copper. Illinois Testing Laboratories, Inc., 141 West Austin Ave., Chicago, Ill.

**THE FOG HORN.** The June issue of this house organ contains testimonial letters on Parks-Cramer air conditioning installations. Parks-Cramer Company, Fitchburg, Mass.

**ELECTRICAL EQUIPMENT FOR THE PETROLEUM INDUSTRY.** Direct mail folders DMF 5239 and DMF 5240 deal with electrification for cable tool drilling and pipe line pumping respectively. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

**POSITIVE RECORD CALORIMETER.** Bulletin gives fitting-up instructions and general details of construction on the Simmance patent positive record calorimeter. Alexander Wright & Co., Ltd., 1 Westminster Palace Gardens, London, S. W. 1, England.

**ACCELERATED WEATHERING.** Weather-Ometer Bulletin 5-30 covers the methods used and apparatus suitable for making various weathering tests. It contains descriptions and prices. Atlas Electric Devices Co., 361 West Superior St., Chicago, Ill.

**AIRCRAFT INSTRUMENTS.** Manual entitled "Principles and Operation of Pioneer Instruments" for instruction purposes in schools, factories and service departments. 24 pages. List Price $2.50. Pioneer Instrument Co., 754 Lexington Ave., Brooklyn, N. Y.

**ENGRAVED THERMOMETERS.** New Catalogue Part 1400 describes and illustrates the various engraved thermometers manufactured by the Taylor Instrument Companies, Rochester, N. Y.

**PYROMETERS.** New Catalogue Part 4000 illustrates and describes the Tycos thermo-electric and radiation pyrometers. Taylor Instrument Companies, Rochester, N. Y.

**INSTRUMENT PRICE LIST.** New price list giving reduced prices on Queen potentiometers, resistance bridges, resistance boxes and shunts. Gray Instrument Co., 64 West Johnson Street, Philadelphia, Pa.

**COIL TESTER.** Bulletin 1090 describes an instrument for detecting short-circuited turns and defective insulation in coils and windings. Rubicon Company, 29 North Sixth Street, Philadelphia, Pa.

**2800 CU. FT. DISPLACEMENT DRY TYPE PROVER.** Leaflet illustrates prover for testing 50,000 cu. ft. per hr. Connersville meter. Connersville Blower Co., Inc., Connersville, Ind.

**INSTRUMENT INVESTMENT NEWS.** The June issue contains the following: Testing Aeroplane Motors; and Modern Hotels-Modern Gauge Boards. Consolidated Ashcroft Hancock Co., Inc., Bridgeport, Conn.

**AVIATION INSTRUMENT INSTRUCTION MANUAL.** 8-page instruction manual for Pioneer instruments covers operation and servicing. Pioneer Instrument Co., 754 Lexington Ave., Brooklyn, N. Y.

**BLAETTER FUER UNTERSUCHUNGS UND FORSCHUNGS INSTRUMENTS.** The May issue of this house organ contains articles on Microchemistry and Microphotography. This is printed in German. Emil Busch A. G., Rathenow, Germany.

**STEELOSCOPES.** Leaflet describes the application of spectroscopes for the rapid estimation of nickel, chromium, molybdenum, titanium, etc., in steel. Adam Hilger, Ltd., 24 Rochester Place, London, N. W. 1, England.

**HIGH-SPEED ENGINE INDICATOR.** Leaflet describes the Rapid-Indicator for indicating engines with speeds up to 2500 rpm. This is printed in English. Lehmann & Michels Abt. I, Hamburg-Altoona, Germany.

**MEAN PRESSURE INDICATOR.** Leaflet describes the Pi-meter for determining the mean indicated pressure in reciprocating engines. This is printed in English. Lehmann & Michels, Abt. I, Hamburg-Altoona, Germany.

**HEAT TREATMENT OF STEEL.** Catalog 90 is entitled "The Hump Method for Heat Treatment of Steel." This new issue is similar to the last edition except that it contains a presentation of the problem of control of the rate of heating above the critical with the same precision as below it. The new portion of the catalogue centers around the control of the rate of heating in and above the critical as precisely as below it, and shows how such control can be secured manually, or by means of automatic control of the rate of heating of the hump furnace. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

**WATER WORKS JOURNAL.** The June issue of the Water Works Journal contains: Lake Waco Water Supply Project; The Determining Factors in Judging a Domestic and Industrial Water Supply; and Metering of City Water Proposed as Overflow at Croton Dam Ceases. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

**GAS SERVICE JOURNAL.** The June issue of this publication contains the following articles: Proving Iron Domestic Meters with Cover Removed; Public Utility Storekeeping; The Search for Ice; and Butane and its Combustion. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

**RECORDING CALORIMETER.** Bulletin describes the "Fairweather" total heat continuous recording calorimeter. Operating instructions are also included. Scientific & Projections, Ltd., Farringdon Road, London, E. C. 1, England.

**RADIO INSTRUMENTS.** Leaflet illustrates several new radio instruments. Weston Electrical Instrument Corporation, 591 Frelinghuysen Ave., Newark, N. J.

**SPECTRUM ANALYSIS.** Bulletin 2 is devoted to Spectrum Analysis and covers the quantitative analysis of metals, bibliography of recent papers, specifications for lead, copper and zinc, etc. Adam Hilger, Ltd., 24 Rochester Place, London, N. W. 1, England.

**HYDROGEN MEASUREMENTS.** L & N Notebook 3 "Notes on Hydrogen Ion Measurements" is not a catalogue, the only reference to Leeds & Northrup is on page 27 of the text in identification of another publication giving information supplemental to the subject. The major portion of the text is devoted to a description of apparatus employed for measuring pH. It tells not only what the apparatus is but how it is used and what its limitations are. Fundamental principles are briefly discussed in a manner and in terms which are comprehensible to one not an expert. Leeds & Northrup Co., 4901 Stenton Ave., Philadelphia, Pa.

**GRAPHIC INSTRUMENTS IN INDUSTRY.** Bulletin 6301 discusses the permanent installation of graphic instruments in industry. Points considered are: economy in cost of power, elimination of labor costs, performance of individual machines, continuous inspection of products and processing, and speed recorders for continuous processing. Esterline-Angus Co., Indianapolis, Ind.

**QUINHYDRONE pH INDICATOR.** Leaflet illustrates applications of the quinhydrone pH indicator. Leeds & Northrup Company, 4901 Stenton Ave., Philadelphia, Pa.


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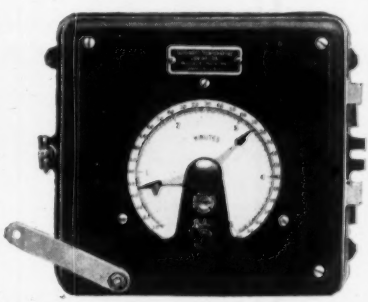

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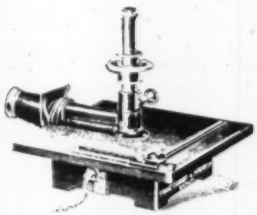

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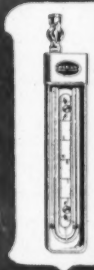

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# CURRENT LITERATURE REVIEW

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## TEMPERATURE & MOISTURE

**A New Regulator Allowing Rapid Changes in the Temperature Setting of the Thermostat.** Milton J. Polissar. Journal American Chemical Society, Feb. 1930, pages 636-637.

The note describes an interesting thermoregulator of the liquid-vapor type. Diagram is given.—M. E. H.

**Measuring Temperatures of Colored Flames Optically.** (Optische Temperaturmessung an gefarbten Flammen). H. Schmidt. Stahl und Eisen, Jan. 23, 1930, pages 106-107.

Two optical methods to determine high temperatures, as for instance temperatures in an open hearth furnace, are considered. The one method is based on the reversion of the spectrum lines according to Kurlbaum and the other on the observation of the spectrum of the means which are applied for coloring flames. Alkali or alkali earth metals are used in this case.—G. N.

**An Electrical Method for the Determination of the Dew-Point of Flue Gases.** Henry Frazer Johnstone. Circular 20, Engineering Experiment Station, University of Illinois, Nov. 1929. 22 pages.

The author discusses the importance of determination of dew-point of flue gases and the difficulty of determination. An electrical method is described and the results obtained are given.

**New Electric Furnace Temperature Controllers.** Electrical Review, March 14, 1930, page 515.

Description of a new type placed on the market by J. Finer. Made in two types, one for furnaces working up to 500°C. and the other for furnaces up to 1200°C. The operating principle of both is the same. It is claimed that the controller will maintain a furnace constant at any predetermined temperature up to 1200°C. with a variation of ±1°.—M. S.

**Temperature Measurement Based on Air Flow Measurements** (Temperaturmessung auf stroemungs technischer Grundlage) H. K. Lehr. Messtechnik, April 1930, pages 93-95.

This article discusses the relation between volume of gas passing through an orifice and the temperature. It then describes an arrangement using the principle of the Wheatstone bridge idea in which 4 equal orifices are used, the temperature of three of them being known, thus permitting the calculation of the temperature of the gas passing through the 4th orifice. The errors of this method are enumerated. It is stated that this device replaces the cumbersome and unsatisfactory aspiration pyrometer.

**A New High Speed Temperature Recorder** (Ein neuer Schnellschreiber in der Waerme-Messtechnik) Zeitschrift fuer Feinmechanik und Praezision, Jan. 31, 1930, pages 6-8.

A new method of recording is described, 50 records per second can be made by this system.

**Two Wholly New Simple Optical Pyrometers for Temperatures Between 600-2000°C** (Zwei ganz neue einfache optische Pyrometer zur Temperaturmessung zwischen 600-2000°C) Zeitschrift fuer Feinmechanik und Praezision, Dec. 18, 1929, page 1-2.

Two glass wedge pyrometers manufactured by Stroehlein & Co. are described: one is an ordinary smoked glass wedge which absorbs the light rays of the hot body; the other is a green glass wedge which absorbs the complimentary color ratiated by the hot body.

**Temperature Measurements on Running Belts.** (Temperaturemessungen an laufenden Riemen) H. Brandt. Messtechnik, March 1930, pages 61-65; April 1930, pages 95-97.

The properties of rubberized fabric for transmission belting are considered. The occurance of increased temperatures due to slip is discussed and a test set-up and the measuring instruments are described.

**The Use of the Grid Glow Tube in a Thermoregulator.** James H. Hibben. Review of Scientific Instruments, May 1930, pages 285-288.

A method of thermoregulation using the neon filled grid glow tube was described and its application discussed.

**Automatic Temperature Regulators** (Selbsttatige Temperaturregler der Firma Buttermann & Schmidt). Elektrotechnische Zeitschrift, Feb. 27, 1930, pages 319-320.

By immersing a metal bar or diaphragm in the hot liquid the expansion of the metal is used for automatically closing and opening the heating current. The instruments are built in ranges of from 40° to 100°, 100° to 600°, and 500° to 900°C. $H_a$.

## HEAT UNIT & COMBUSTION

**The Heat Capacity of Saturated Liquid Ethane from the Boiling Point to the Critical Temperature and Heat of Fusion of the Solid.** R. Wiebe, K. H. Hubbard & M. J. Brevoort. Journal American Chemical Society, Feb. 1930, pages 611-622.

One low-pressure and one high-pressure calorimeter for determinations of heat capacities of liquids below room temperatures under their saturation pressure are described.—M. E. H.

**Calorimetry of a Fluid.** Nathan S. Osborne. Bureau of Standards, Journal of Research, May 1930, pages 609-629.

In this paper a calorimetric method of determining the thermodynamic characteristics of a fluid is outlined. The basic principles involved and the application of the method to formulation of thermal properties for engineering uses are both analyzed. The method has been developed at the Bureau of Standards for determining the properties of steam. A single calorimetric apparatus specially designed and with especial refinements provides a setting for a systematic group of experiments of four types in which four characteristic heat quantities are determined each as a function of temperature. These experimental data provide a basis for formulation of the thermodynamic behavior of the fluid in terms of familiar and convenient properties within the limits of the observations.

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## WEIGHING, SPECIFIC GRAVITY, DENSITY

**Development of Scale Design Through a Century.** R. H. Bacon. Scale Journal, April 10, 193 pages 7-8.
A brief historical sketch.

**Special Scales.** H. O. Hem. Scale Journal, May 10, 1930, pages 7-8.
Various special production scales are briefly described: Auto-gage for standardizing pistons combination piston ring and valve spring auto-gage; chassis spring testing machine, etc. Paper read before National Scale Men's Convention, March 12, 1930, Chicago.

**Various Type Scales in Use Today.** J. E. Woodland. Scale Journal, May 10, 1930, pages 9-10
Paper read before National Scale Men's Convention, March 12, 1930, Chicago. Brief discussion of scale applications.

**Automatic Filling and Counting Scales** (Automatische Abfuell und Stueckzaehl-Waagen) Zeitschrift fuer Feinmechanik und Praezision, Oct. 31, 1929, pages 4-5.
The scales manufactured by the Merseburger Waagenfabrik A. Dresdner, Merseburg a. S. Germany are briefly described.

## VIBRATION, SOUND, LIGHT, COLOR

**Sensitive and Manometric Flames.** R. C. Colwell. Review of Scientific Instruments, June 193 pages 347-350.
Sensitive and manometric flames and burners are discussed briefly.

**A Sensitive Method for Determining Refractive Indices.** S. A. Korff & J. Q. Stewart. Review Scientific Instruments, June 1930, pages 341-346.
A combination of Michelson interferometer and spectroscope is described which has proved useful in giving accurate values of the refractive indices of vapors, especially near absorption lines. The method involves measurements, easily made, of wave lengths of fringes seen in the spectroscope. Photographs of the fringes are given. The combination also provides an interesting method for putting along a spectrum a natural scale of frequencies, provided by these fringes.

**The Reflection Factor of Magnesium Oxide.** J. S. Preston. Transactions Optical Society, Vol. 1929-1930, No. 1, pages 15-35.
This paper describes the design and use of a small integrating reflectometer for determining the total reflection factor of a smoked magnesium oxide surface under diffuse illumination. It also shows how the reflectometer may be used for the absolute determination of apparent reflection factors (reflectances) under parallel illumination. The instrument depends on the change in brightness of the walls of a small integrating sphere which occurs on removal of a test plate covering a circular aperture of known area in the sphere. The theory is extended to show how the interior of the sphere may be used as a standard of brightness when the diffuse reflection factor of the coating and the flux entering the sphere are known. This affords a new means for the standardization of photometric test plates. A second method of determining the diffuse reflection factor of the reflectometer coating is described depending on measurements of the brightness of the interior of the sphere and of an artificial sky used to illuminate it through the aperture.

**A History of the Development of the Telescope from about 1675 to 1830 Based on Documents in the Court Collection.** Thomas H. Court & Moritz von Rohr. Transactions Optical Society, May 1930, pages 207-260.
The optics of the telescope as known when its manufacture was commenced in England. Lieberhey's influence on the Continent and in England; A. M. v. Schyrle's great invention of the terrestrial telescope with image-erecting lenses in 1645 (made in Augsburg). The old refracting telescopes in England. Sir Charles Cavendish's acquaintance with A. M. v. Schyrle and some points of similarity between Cock's terrestrial telescope of 1673 and A. M. v. Schyrle's description of 1645. Popularity of telescopes of Schyrle's planning in England in the seventeenth and eighteenth centuries. English improvements and night telescopes. The reflecting telescopes after Gregory and Newton, and their manufacture in London. The original work of Gregory and of Newton. J. Hadley's impulse; influence on English opticians; Passement's form in 1738; Short's splendid instruments. Caleb Smith's improvement in 1740 and the first publication of his principle of color correction. Chester Moor Hall's invention of the achromatic telescope (1729-33) and its marketing by John Dollond (1758). Relation of the already known facts in historical sequence; invention certainly known to the trade in 1754. J. Dollond's re-invention and publication. Prices of such instruments before and after J. Dollond's death in 1761 and Lord Camden's decision in 1766. P. Dollond's policy as to the prices for achromatic telescopes. A digression concerning the gradual appreciation of Chester Moor Hall's merits. The publications of A. M. de Rochon and Monton and the work of the more modern investigators A. C. Ranyard, R. B. Prosser, and E. Wyndham Hulme. Sir William Herschel's reflectors. Knowledge enlarged by Prince Troubetzkoj and W. H. Steavenson. Herschel's influence on English and foreign opticians beyond the period treated here. The earlier endeavours to avoid a secondary spectrum. A. C. Clairaut in 1762, R. J. Foscovich about 1767 and R. Blair after 1787, employing different fluids. Later improvements and modifications of the achromatic telescope. P. Dollond; H. Pyefinch; brass draw-tubes about 1783; stands folding into a very small compass; W. Worris; C. Varley; the problem of optical glass. The first knowledge of Fraunhofer's instruments; French astronomical objectives of large diameter; the order to Fraunhofer in Munich from Edinburgh Observatory.

**Drum Polarisation—Apparatus** (Trommel—Polarisations—Apparat) Zeitschrift fuer Feinmechanik und Praezision, Feb. 15, 1930, pages 6-7.
Brief description of this instrument manufactured by Steindorff, Berlin.

**The Measurement and Analysis of Mechanical Vibrations** (Beitrag zur Messung und Analyse Mechanischer Schwingungen) Heinrich Hoffman. Messtechnik, March 1930, pages 65-69
A mathematical discussion, considering the measurement in one component, two components and the resultant. Other points considered are vibration maximum, true shape of the vibration in a plane, surface vibration; linear vibration, importance of phase displacement, method of taking polar diagrams.

**An Aid to the Investigation of Vibration of Running Machinery.** C. H. Wright. Instrument World, May 1930, pages 5-6.
The application of the K. B. B. vibrometer to the measurement of vibration is briefly described

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Weston Elec. Inst. Corp.

**Controlling**
Leeds & Northrup Co.

**Recording**
Bristol Company
Esterline-Angus Company
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**Standards**
General Radio Co.

**FUEL ANALYSIS APPARATUS**
Burgess-Parr Co.

**FUEL FLOW INDICATOR**
Commercial Engg. Labs.

**GALVANOMETERS**
Brown Instrument Co.
Charles Engelhard, Inc.
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

**GAS ANALYTICAL METERS**

**Chemical**
American Meter Co.
Tagliabue Mfg. Co., C. J.

**Electrical**
Brown Instrument Co.
Charles Engelhard, Inc.
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**GAS LEAK INDICATORS**
Taylor Instrument Companies

**GAS-METERS**
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

**GASOMETERS**
American Meter Co

**GAGE RODS**
Tagliabue Mfg. Co., C. J.

**GAGES**

**Absolute Pressure**
Bristol Company
Brown Instrument Co.
Foxboro Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

**Amplifying**
B. C. Ames Co.
Federal Products Corp.

**Comparator**
B. C. Ames Co.
Federal Products Corp.

**Cylinder**
B. C. Ames Co.
Federal Products Corp.

**Depth**
B. C. Ames Co.
Federal Products Corp.

**Dial**
B. C. Ames Co.
Federal Products Corp.
H. Z. Schniewind

**Differential Pressure**
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.

**Draft**
Bristol Company
Brown Instrument Co.
Foxboro Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

**Drill**
Bausch & Lomb Optical Co.

**Grinding**
Federal Products Corp.

**Liquid Level**
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

**Loss of Head**
Brown Instrument Co.
Foxboro Co.
Meriam Co.

**Pitch Diameter**
Federal Products Corp.

**Pocket**
H. Z. Schniewind

**Pressure**
American Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

**Pressure-Temperature**
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.

**Pressure & Vacuum**
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
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Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

**Profile**
Bausch & Lomb Optical Co.

**Rain**
Taylor Instrument Companies

**The Effect of Glare on the Brightness Difference Threshold.** Department of Scientific & Industrial Research, Technical Paper No. 8, 64 pages.

One of the outstanding problems confronting the illuminating engineer is the reduction and, if possible, the elimination of glare. Before this problem can be dealt with successfully more exact knowledge of the diverse effects of glare must be made available. The present technical paper is a contribution to this end. One important aspect of glare, the reduction in ability to see, has been subjected to measurement over the range of the variables—glare intensity, general brightness level, glare source position, etc.—corresponding to practical lighting conditions such as are shown in street lighting, illumination by motor car headlights, etc. The results of some 15,000 measurements are summed up in a formula by the aid of which the reduction in ability to see produced by a glare source of light in any particular case can be computed. A complete description of the methods and apparatus employed in the investigation is included. Tables of the principal experimental results are reproduced. In addition to the main outcome of the work—the empirical formula referred to above—the results lead to certain deductions as to the possible mechanism of the glare effect. In an appendix, a method for measuring the diameter of the eye pupil in the presence of glare is described; data on this point are submitted. Application of the glare formula derived in this Paper to actual lighting installations has already been made and the predicted glare effects have been confirmed by practical tests on the full-scale installations. The following is a list of the contents of the report:—Part I. Introduction, The Observational Conditions, Description of Apparatus, The Subjects, Absence of Glare, Glare Conditions, Summary. Part II. Introduction, The Measurements, General Theoretical Considerations, Summary. Part III. Introduction, Experimental Conditions, Results. Appendix. Measurements of Pupil Dimensions.

## CHEMICAL ANALYSIS & APPARATUS

**The Temperature Coefficient of the Synthesis of Hydrogen Chloride by Light and by Alpha-Radiation.** S. C. Lind & Robert Livingston. Journal American Chemical Society, Feb. 1930, pages 593-608.

The photochemical (white light) and radiochemical synthesis of HCl have temperature coefficients which are identical within the limits of experimental error. The apparatus used was a modified Bunsen and Roscoe actinometer, similar to that employed by Porter, Bardwell and Lind (Ibid. 48, 2603 (1926)—M. E. H.

**Hydrogen Peroxide. VII. The Dielectric Constants, Refractive Indices and Ionizing Power of Hydrogen Peroxide and Its Aqueous Solutions.** A. C. Cuthbertson & O. Maass. Journal American Chemical Society, Feb. 1930, pages 489-499.

The dielectric constants and the refractive indices for hydrogen peroxide and its aqueous solutions were measured. A method is described for measuring electric conductances in hydrogen peroxide and its solutions.—M. E. H.

**The Relative Rates of Absorption of the Gaseous Olefins into Sulfuric Acid at 25 Degrees.** Harold S. Davis & Reuben Schuler. Journal American Chemical Society, Feb. 1930, pages 721-7[illegible]

Measurements have been carried out on the rates of absorption of olefin gases into sulphuric acid at constant volume by following the change in the pressure with time. Apparatus is diagrammed.—M. E. H.

**A Method for the Determination of Uronic Acids.** Allan D. Dickson, Henry Otterson & Karl Paul Link. Journal American Chemical Society, Feb. 1930, pages 775-779.

An apparatus and method, a modification of the Lefèvre-Tollens method, for the accurate determination of uronic acids by decarboxylation with HCl (sp. gr. 1.06) are given.—M. E. H.

**Study in Auto-Oxidation Reactions.** I. Oxidation of Anethol, etc. Nicholas A. Milas. Journal American Chemical Society, Feb. 1930, pages 739-753.

An improved method and apparatus are described for the determination of oxygen absorption rates in auto-oxidation reactions, especially in oxidations in which gaseous products are evolved.—M. E. H.

**The Composition of Constant Boiling Hydrochloric Acid at Pressures of 50 to 1220 Millimeters.** Walter D. Bonner & Albert C. Titus. Journal American Chemical Society, February 1930, pages 633-635.

The composition and density of constant boiling HCl acid between 50 and 1220 mm. have been determined. An equation is given by the aid of which the composition of any constant boiling HCl acid may be computed from its density at 25 degrees. The use of this acid as a primary standard in acidimetry is thus simplified.—M. E. H.

**The Dielectric Constants of Water at Various Temperatures.** A. C. Cuthbertson and O. Maass. Journal American Chemical Society, Feb. 1930, pages 483-489.

A resonance method for the measurements of the dielectric constant of pure liquids is described involving the use of a variable dielectric cell in which lead and end effects are eliminated and the dimensions of which can be altered over wide limits. The dielectric constants of ether, benzene, chlorobenzene and nitrobenzene were measured at 25°. The dielectric constant for water was determined between 0 and 75. The step-by-step method used made it possible to make absolute measurements based on air as unity.—M. E. H.

**Photochemical Studies. X. The Electronic and Photochemical Decompositions of Potassium Chlorate.** John G. Meiler & W. Albert Noyes, Jr. Journal American Chemical Society, Feb. 1930, pages 527-533.

An attempt has been made to study the decomposition of solid potassium chlorate by bombardment with slow electrons. The results indicate that decomposition may be brought about by [illegible] volt electrons. Results with lower voltages are somewhat inconclusive but are, on the whole, negative.—M. E. H.

**Potentiometric Titrations of Phosphates, Arsenates and Arsenites With Silver Nitrate.** M. Helen Bedford, Frances Roberts Lamb & W. Edward Spicer. Journal American Chemical Society, Feb. 1930, pages 583-588.

Use has been made of a secondary titration with NaOH to maintain the desired low H-ion concentration. The phosphate titration proved the least satisfactory.—M. E. H.

**A Recording Control and Alarm Instrument of Many Uses** (Ein vielseitiges selbstschreibendes Kontroll-und Alarmgeraet). Elektrotechnische Zeitschrift, March 20, 1930 pages 430-431.

The article describes a modification of a Leeds & Northrup recorder for the special purpose of continuous control of the hydrogen ion-content of the solution in the sugar refining process. The whole arrangement is described in detail. H[illegible]

Recording
Distance
Bristol Company
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Esterline-Angus Company
Strain
Southwark Fdry. & Mach. Co.
Thickness
B. C. Ames Co.
Esterline-Angus Company
H. Z. Schniewind
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**HUMIDITY RECORDERS**
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Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

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Indicating
Leeds & Northrup Co.
Rubicon Company
Controlling, Recording
Leeds & Northrup Co.

**HYDROMETERS**
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

**HYGROMETERS**
Brown Instrument Co.
Foxboro Co.
H. Z. Schniewind
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

**IMPACT HARDNESS TESTER**
H. Z. Schniewind

**IMPACT TESTING MACHINES**
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H. Z. Schniewind
Alternating

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H. Z. Schniewind

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Prism
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Foxboro Co.
Meriam Co.

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American Meter Co.

**METER TESTERS, Gas**
American Meter Co.

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H. Z. Schniewind

**MICROAMMETERS**
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

**MICROFARADMETERS**
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Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.

**MICRO PYROMETERS**
Akatos, Inc.

**MICROSCOPES**
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Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
H. Z. Schniewind
Spencer Lens Co.
Metallographic
Akatos, Inc.
Bausch & Lomb Optical Co.
Spencer Lens Co.
Petrographical
Akatos, Inc.
Bausch & Lomb Optical Co.
Spencer Lens Co.
Toolmakers'
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Spencer Lens Co.

**MICROTOMES**
Bausch & Lomb Optical Co.
Spencer Lens Co.

**MILLIAMMETERS**
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General Radio Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

**MILLIVOLTMETERS**
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Charles Engelhard, Inc.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co
Taylor Instrument Companies
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

**MOTOR RADIATOR VALVES**
Minneapolis-Honeywell Co.

**MOTION RECORDERS**
Mechanical
Bristol Company
Foxboro Co.
Lehmann & Michels

**MULTIMETERS**
Rawson Electrical Instrument Co

**MULTIPLIERS**
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Weston Electrical Inst. Corp.

**NEON FILLED TUBES**
Argco Laboratories, Inc.

**NEPHELOMETERS**
Akatos, Inc.

**OHM METERS**
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co
Rubicon Company
Herman H. Sticht and Company
Weston Electrical Inst. Corp.

**OIL TESTING APPARATUS**
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

**A Method for the Determination of the True Acid Value of Oils, Varnishes, Liquid Driers and Soaps** E. W. Dener & S. W. Werthan. Preprint No. 98, Americal Society for Testing Materials June 23-27, 1930, 4 pages.

A method for the determination of acid value is given which eliminates inaccuracies due to the dissociation of metallic soaps. The metals present as soaps are quantitatively precipitated as insoluble oxalates with the liberation of acid. The procedure is to reflux the sample in an alcoholic benzene mixture with a measured quantity of standard oxalic acid solution and then titrate the total acidity with a standard alcoholic potassium hydroxide solution using phenolphthalein as indicator. The difference between this titration and the equivalent of the oxalic acid added is a measure of the true acid value. The method also affords a means for determining the total amount of metallic soaps present. Data are given establishing the accuracy of the method.

## X-RAY TESTING & EXAMINATION

**Some New Experiments on the Chemical Effects of X-Rays and the Energy Relations Involved** George L. Clark & Lucy W. Pickett. Journal American Chemical Society, Feb. 1930, pages 465-479.

Several chemical systems which are known to undergo photochemical change in ultraviolet light are investigated with x-rays, in most cases of an effective wave length of 0.24 A. U. Most of the changes, if any, are small. The most sensitive reactions found besides oxidation of solutions of ferrous to ferric salts are a series of aldehyde-ketone condensations, investigated for the first time photochemically. Other systems studied are $KNO_3$, $KIO_3$-$KNO_3$, KI-$KNO_3$, colloidal lead and colloidal clay.—M. E. H.

**X-Ray Inspection of Heavy Castings.** Ancel St. John & Herbert R. Isenburger. Machinery, Feb. 1930, pages 431-434.

Gives a general description of the X-ray equipment used in testing castings weighing over three tons. A 200,000 volt direct current was used in making this inspection.—R. H. P.

**Precision Measurements of X-Ray Reflections from Crystal Powders.** J. Brentano. London, Edinburgh, & Dublin Philosophical Magazine & Journal of Science, Mar. 1930, pages 525-538.

Discussion of the relative value of the Davey apparatus and powder rod, and of the focussing method for the determination of the lattice spacing of cadmium oxide. Compares the results obtained by the use of each.—R. H. P.

## MICROSCOPY

**The Creation of a Microscope Objective.** Instrument World, May 1930, pages 15-20.

Reprinted from The Technical Instrument Bulletin. The design and construction of a microscope objective is described.

**A New Research Microscope.** W. L. Patterson. Review of Scientific Instruments, May 1930, pages 292-294.

A new model of microscope is described.

**The Microscopical Examination of Coal.** C. A. Seyler. Physical & Chemical Survey of National Coal Resources No. 16, Department of Scientific & Industrial Research, 64 pages, 2 sh. 6d.

This report records some of the results on the microscopical examination of coal during the past few years. An account is given of the method of preparing thin sections of coal for examination by transmitted light, but the report is chiefly concerned with the methods of, and the results obtained by, polishing and etching flat surfaces of coal. This method, which is based on metallographic practice, and was first applied to coal by Winter, has been modified and developed by Seyler. By its aid plant structures in coal have been shown to be far more numerous than was previously supposed, and there is the further advantage that sections can be prepared in three determined planes meeting at right angles in a selected part of a plant fragment, which is essential to the interpretation of structure. The report also includes a description of a simple photomicrographic apparatus, with manipulative details, particularly with regard to photography by vertical illumination. The technical side of the work is followed by an account of the cell structures found in coal and of their various states of preservation, and of the identification of definite plant tissues.

## SPECIAL

**Making Precision Worm-wheels of Large Size.** O. G. Simmons. Machinery, Mar. 1930, page 55

Describes a precision worm and worm wheel having a maximum angular movement error of 2 seconds. It is used as a precision indexing device for use in a gear cutting machine for the manufacture of automobile gears.—R. H. P.

**The Measurement of Lubrication of Oil** (Die Messung der Schmierfaehigkeit von Oelen) Vieweg. Deutscher Verband fuer die Materialpruefungen der Technik. Beilage zu Heft 17, March 1930, 7 pages.

Old and newer viewpoints on bearing friction and lubrication are discussed. The tests, to determine the lubricating properties of oils carried at the Physikalisch-Technischen Reichsanstalt to explain the lubricating process, are considered.

**Methods and Instruments to Test Aviation Photographic Devices** (Einige Methoden und Instrumente zur Pruefung von Aero—Lichtbildgeraeten) Hans Beck. Zeitschrift fuer Feinmechanik und Praezision, April 18, 1930, pages 1-6.

Methods and devices described. Paper read before the Deutsche Gesellschaft fuer Mechanik und Optik.

**An Optical Measuring Device for Model Aeroplane Propellers** (Eine optische Vermessungseinrichtung fur Modell—Luftschrauben) Carl Ort. Messtechnik, April 1930, pages 89-93.

The article briefly describes two devices for the measurement of propellers: a device for photographically recording the propeller profile and a device for determining the numerical values of the profiles obtained.

**Care and Adjustment of Folding Testers of the Schopper Type.** Circular 379, U. S. Bureau of Standards, 1929, 7 pages.

Because of the importance of the folding test as a criterion of the durability of papers and the difficulty of keeping folding testers of the Schopper type in proper condition considerable attention has been given to their care and adjustment. Brief reference is made to a previous publication in which was described a device designed to facilitate adjusting the tension on the specimen. The device, which is a deadweight tester involving the use of a balanced bell-crank lever, has been improved and has been adapted to the measurement of the friction of the rollers. This method of measuring roller friction is described, and a number of suggestions are made concerning the care and adjustment of the folding tester. A procedure is outlined for the periodic inspection and adjustment of the tester.

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Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

**ORIFICE METERS**
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Brown Instrument Co.
Foxboro Co.
Meriam Co.

**ORSAT APPARATUS**

**OSCILLOGRAPHS**
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Westinghouse Elec. & Mfg. Co.

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**PHOTOMETERS**
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H. Z. Schniewind
Southwark Fdry. & Mach. Co.

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Brown Instrument Co.
Foxboro Co.

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Brown Instrument Co.
Linear
Brown Instrument Co.
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Radial
American Meter Co.
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Gaertner Scientific Corp.

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**POTENTIAL DETECTORS**
Leeds & Northrup Co.
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**POTENTIOMETERS—Indicating**
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**POWER FACTOR METERS**
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Jewell Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Eelectrical Inst. Corp.

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Rubicon Company
Westinghouse Elec. & Mfg. Co.

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Esterline-Angus Company
Foxboro Co.

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Stromberg Electric Co.

**PROJECTION LANTERNS**
Bausch & Lomb Optical Co.
Spencer Lens Co.

**PROTRACTOR**
Optical
Bausch & Lomb Optical Co.

**PSYCHROMETER**
Recording
Bristol Company
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Sling
Taylor Instrument Companies

**PYROMETERS**
Optical
Leeds & Northrup Co.
Pyrometer Instrument Company
Radiation
Indicating
Brown Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
Recording
Brown Instrument Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Thermo-electric
Immersion
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Indicating
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Taylor Instrument Companies
Westinghouse Elec. & Mfg. Co.
Wilson-Maeulen Company, Inc.
Recording and Controlling
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Surface Contact
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies

**RADIO FREQUENCY OSCILLATORS**
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**RADIO SET ANALYZERS**
General Radio Company
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

**RADIO TUBE CHECKERS**
General Radio Company
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

**RADIO TEST PANEL**
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

**REFRACTOMETERS**
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Bausch & Lomb Optical Co.
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Westinghouse Elec. & Mfg. Co.
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Brown Instrument Co.
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Bausch & Lomb Optical Co.
Spencer Lens Co.
Taylor Instrument Companies

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Tagliabue Mfg. Co., C. J

**SALINITY INDICATORS**
Rubicon Company

**SCALES**
Amthor Testing Instrument Co
Gaertner Scientific Corp.
H. Z. Schniewind

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**SHUNT METERS**

**SHUNTS**
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Leeds & Northrup Co.
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Charles Engelhard, Inc.
Esterline-Angus Company
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co
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**Pressure Measurements on Roll Bearings** (Druckmessungen an Walzenlagern.) Otto von Auwers. Wissenschaftliche Veroffentlichungen aus dem Siemens-Konzern, VIII Band, Zweites Heft, June 22, 1929, pages 137-143.

Report published by the Research Laboratories at Siemenstadt, Germany. Contains 22 illustrations and 5 references. The paper describes the application of the condenser microphone principle for measuring the pressure exerted upon the bearings of rolling mills in operation. An oscillograph was used for recording the pressure variations.—A. J. M.

**An Electrical Pressure Measuring Device Based on the Condenser Micrometer.** (Eine elektrische Messdose nach dem Prinzip des Kondensatormikrometers.) Hans Gerdien. Wissenschaftliche Veroffentlichungen aus dem Siemens-Konzern, VIII Band, Zweites Heft, June 21, 1929, pages 126-129.

Report published by the Research Laboratories at Siemenstadt, Germany. Contains 4 illustrations. The author describes an electrical measuring device based upon the condenser microphone principle. The capacity of the condenser forms the essential part of the capacity of a high frequency regenerative oscillatory circuit which is supplied with energy by a vacuum tube. The oscillatory circuit is coupled to a system including another vacuum tube which functions as a rectifier, and to which the high frequency currents actuate, after rectification, either a direct current millivoltmeter or an oscillograph, for indicating and/or recording measurements of tensile forces or pressures.—A. J. M.

**Lathe Cutting Pressure Measurements with an Electrical Device.** (Schnittdruckmessungen an der Drehbank mit einer elektrischen Messdose.) Wilhelm Mauksch. Wissenschaftliche Veroffentlichungen aus dem Siemens-Konzern, VIII Band. Zweites Heft, June 22, 1929, pages 130-136.

Report published by the Research Laboratories at Siemenstadt, Germany. Contains 6 illustrations and 8 references. The article deals with possible applications of the condenser microphone principle for measuring cutting pressures of machine tools. An oscillograph is used for recording the pressure variations.—A. J. M.

**Sagmeter for Transmission Lines.** (Der Freileitungsmesser). M. Hoefer. Elektrotechnische Zeitschrift, April 17, 1930, pages 577-578.

A simple apparatus is described which consists of a movable scale on a tripod with adjusting arrangement a fixed distance of 0.5 m from the point of intersection of the lines of vision. The author illustrates how the sag is measured taking into account the perspectivic distortion. The simple outfit costs only $42.00 while telescope apparatus are more than three times that much the results are very accurate. The whole apparatus can be folded up and easily transported. Ba.

**New Gyroscopic Instrument Contributes to Safer Flying.** O. B. Whitaker. The Sperry scope, Vol. 6, No. 2, 1930, pages 4-5.

Briefly illustrates the artificial horizon.

**Application of the Photoelectric Cell to the Measurement of Small Displacements.** J. A. C. Torrance & K. G. Krishnan, London, Edinburg & Dublin Philosophical Magazine & Journal of Science, April 1930, pages 589-592.

Describes and illustrates a method of using the photoelectric cell to measure small displacements.—R. H. P.

**Procedure Used by the Forest Products Laboratory for Evaluating Paint Service on Wood.** F. L. Browne. Preprint No. 92, American Society for Testing Materials, June 23-27, 1930, 19 pages.

The three indexes of serviceableness are defined: (1) appearance, which measures the ability of the coating to hide the underlying surface and maintain an arbitrarily chosen color; (2) integrity, which measures the ability of the coating to remain intact as a continuous film covering the surface; and (3) protection, which measures the ability of the coating to protect the wood from weathering. Failure in one of the three measures of serviceableness necessitates repainting and therefore determines the durability of the coating. Besides the indexes of serviceableness, supplemental information concern-qualities and defects of the coating is collected during inspections for the purpose of throwing light upon the course of the observed changes in the indexes of serviceableness. The qualities gloss, hiding, color cleanliness, and uniformity bear upon the appearance of the coating, while the defects chalking, checking, crumbling, cracking, slitting, flaking, and scaling bear upon its integrity. In each of the indexes, serviceableness is rated either good, fair, poor, or bad at inspections. These ratings are defined in such a way that they can be kept in mind permanently so that results of inspections at different times or places can be compared. The static records of successive inspections are expressed dynamically in terms of the length of time the coating remains in the different ratings. Arbitrary rules are then adopted for defining the durability of the coating based upon consideration of integrity only, and upon consideration of protection as well as integrity and for giving the lowest rating in appearance and the age of the coating when it was attained.

**Hiding Power Measurements in Theory and Application.** A. H. Pfund. Preprint 94, American Society for Testing Materials, June 23-27, 1930, 6 pages.

Tentative definitions for (1) hiding power of a paint and (3) hiding power of a pigment are presented. A new "Black-and-White" cryptometer, based on the above definitions, is described and the usefulness of this instrument for measuring the wet hiding powers for all types and colors of coatings is demonstrated. A precision cryptometer, involving the use of a photoelectric cell in place of the human eye, has been developed. This device, which is extremely sensitive and free from the subjective errors of the human eye, yields precision results of hiding power.

**A Practical Brush-Out Test for Hiding Power of Paints.** H. A. Gardner, G. G. Sward & S. A. Levy. Preprint No. 96, American Society for Testing Materials, June 23-27, 1930, 4 pages.

This paper deals with a practical method of determining hiding power by actually brushing out a paint upon a surface of checkerboard linoleum made up of black and white blocks. The results obtained by this method are compared with results obtained by the Pfund cryptometer, and it is found that the brush-out method gives higher results. The results, however, retain the same order of magnitude.

**Friction Coefficients for Fabric Brake Lining.** P. S. Caldwell. Journal Royal Technical College, Jan. 1930, pages 220-230.

In this paper experiments are described comparing the coefficient of friction with the surface speed of rubbing when bonded ferodo is used as a friction brake lining and cast iron is used for the brake wheel. Attention is drawn to the manner in which the coefficient of friction varies with the load and the running speed. Actual changes of temperature have not so far been measured, but it is indicated that the coefficient of friction varies somewhat with temperature. Tests of the wear of brake lining were carries out for three loads at constant speed, and the results are tabulated and certain deductions made.

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## MISCELLANEOUS

**The Grinding and Etching of Hollow Glassware** (Die Bearbeitung von Hohlglass mit Schleif und Aetzmitteln) Glass und Apparat, April 20, 1930, pages 73-74; May 4, 1930, pages 81-82; May 18, 1930, page 90.

Practical experiences in the working of hollow glassware are given, especially applied to the production of lamp bulbs.

**Technical Testing of Rust Protecting Paints** (Beitrag zur technischen Pruefung von Rostschutzfarben) Friedrich Hoepke. Deutscher Verband fuer die Materialpruefungen der Technik, No. 79, Nov. 1929, 40 pages.

This report shows that with the aid of certain tests it is possible to obtain satisfactory and reproducible results. These tests are considered in detail and the author points out the necessity of additional work along this line in order to set up uniform methods.

**The Testing of Lubricating Oils** (Die Pruefung der Schmiermittel) Deutscher Verband fuer die materialpruefungen der Technik, No. 80, March 1930, 26 pages.

Report of Committee 9 on uniform methods of testing. The following are considered: sampling, specific gravity, cold test, mrlyinh point and softening paint of greases, viscosity emulsification, water content, ash content, solid foreign matter neutralization and soap number.

**Composition and Laboratory Testing of Paints for Boiler Interiors.** (Wesen und laboratoriumsmassige Pruefung von Kesselinnenanstrichmitteln). Hofer. Veroeffentlichungen des Zentral-Verbandes der Preussischen Dampfkessel-Ueberwachungs-Vereine. Vol. VI, 1929, pages 85-95.

Boilers using water which is not treated can be painted on the inside to facilitate the removal of scale. The 41 commercial paints examined consist of 3 groups: I Solutions of bituminous materials in hydrocarbons, and tar and oil residues, sometimes with the addition of graphite, II Suspensions of graphite in linseed oil, mineral oil and water containing organic colloids, and III Suspensions of metallic oxides in linseed oil. Typical analyses of each group are given, but this is not sufficient to determine their usefulness. Elasticity of the film is tested by bending thin sheets coated with paint around rods of various diameters. Paints in group I and linseed oil suspensions of group II withstood this test very well, but not the water suspensions of graphite. Stainless Steel test sheets coated with paint were weighed and hung in boiling water twice for 10 hours and loss in weight determined. In tests using water containing soda the linseed oil paints saponify and flake off. Precautions are given for applying paints with low flash points. Tests show that the heat transfer is not hindered by relatively thin coats of paint.—C. E. M.

**The "Servis" Recorder.** Iron & Coal Trade Review, Supplement, Jan. 3, 1930, page II.

Recorder to check the running and the standing time of a vehicle. The record is made by a sapphire-pointed stylus which scrapes a colored wax coating from the surface of a 24 hour chart. A straight line is made when standing and an uneven one when the vehicle is in motion. It is built by the Servis Recorders, Ltd., Eagle St. London, W. C.—R. H. P.

**A Stroboscopic Ripple Tank.** William Baldwin, Jr. Review of Scientific Instruments, June 1930, pages 309-324.

A form of ripple tank is described in which the point source of waves is simply a succession of periodic air blasts directed downward onto the surface of the water. Two or more such sources can be used simultaneously and their positions are readily changed from place to place. For the production of rectilinear waves a pulsating linear vibrator is described. For the study and projection of water waves an adjustable stroboscope is used, which can either be driven in strict synchronism and in any desired phase relation with the air blasts, or slowly advanced in one direction or the other. Thus the wave images can be made to advance or retreat across the screen and to stop at any desired stage. The series of photographs show some of the possibilities of the device in demonstrating reflection, refraction, interference, and diffraction of waves.

**The Limit of Grip Due to Force Fits and Its Increase by Coldworking.** R. Russel & J. Shannon. Journal Royal Technical College, Jan. 1930, pages 250-267.

This paper deals with the results of an experimental study of force fits. Small steel rings and solid plugs are used with increasing fit allowances. The limit value of the longitudinal grip between the parts is studied, and it is shown that the grip is a maximum at the fit allowance corresponding to the yield point indicated by the strain energy criterion of failure. It is demonstrated that it is impossible to improve the grip after the yield point has been passed by merely employing excessive allowances. The possibility of improving the grip by initial coldworking is examined. Coldworking by excessive fit allowance is adopted. This increases the proof resilience and a greater grip is possible without permanent set on refitting. Under all conditions the grip between the parts seems to be due to the recoverable elasticity of the material of the ring as represented and measured by the "residual" fit allowance shown after withdrawal.

**Glass Fibers for Reticules.** D. L. Parkhurst. Review of Scientific Instruments, June 1930, pages 329-331.

Telescope and microscope cross-wire systems are divided into four classes: the ruled glass diaphragm, the metal fiber, spider threads and a new fiber of spun glass. The method of producing the fiber is described, as well as its mounting and advantages.

**The B. T. H. Laboratories.** H. Warren & A. E. Smith. Electrician Vol. 104, Apr. 11, 1930, page 461.

The General Laboratory of the B. T. H. Co. at Rugby is briefly described. The laboratory occupies two floors of a steel frame and brick building—W. H. B.

**The Insensitivity and Personal Equator Errors of Optical Settings.** J. Guild. Transactions Optical Society, Vol. 31, 1929-1930, No. 1, pages 1-14.

The paper contains the results of observations on the insensitivity, that is, mean difference of the individual observations of a large series from the mean of the series, in the case of X type graticules set on vertical object lines. The influence of the following factors was investigated: (1) Thickness of cross-wires. (2) Angle between cross-wires. (3) Field brightness. (4) Pupillary aperture. Observations were also made of the magnitude of the "personal equation" error in such settings.

## CALCULATION

**Water-Flow Chart.** Sydney C. Mifflen. Engineering & Mining Journal, Feb. 14, 1930, page 201.

A chart is shown which is applicable to the flow of water through average cast iron and wrought iron pipes in fair interior condition. Knowing any 2 of the following factors—pipe diameter, discharge velocity, or feet head lost in friction per 1000 ft. lengths of pipe—a straight edge laid across the chart connecting the two known values will indicate the two unknown all on their respective scales. The nominal diameter of a pipe is not the exact internal diameter, and provision for this is made in the graduation of the diameter scale for diameters up to 12". For greater diameters measurements are taken of the outside diameters and twice the wall thickness deducted to secure the actual inside diameter.—W. H. B.

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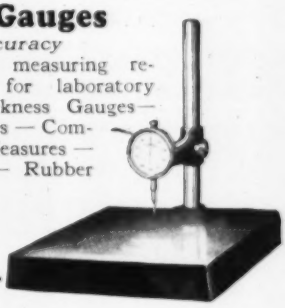


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How Hair Springs are Made.

**HENRY SUGDEN,** INSTRUMENTS, Vol. 3, No. 8, August, 1930, pages 482-484, 6 figs.

Methods and apparatus described.

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Instrument Repair and Standardization Laboratory.

**C. E. FRY,** INSTRUMENTS, Vol. 3, No. 8, August, 1930, pages 485-488, 1 fig.

Routine used by the Westinghouse Electric and Manufacturing Co., discussed.

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Measurement of Air Flow.

**E. OWER,** INSTRUMENTS, Vol. 3, No. 8, August, 1930, pages 489-499, 2 figs.

Chapter VI. The plate orifice, venture tube and shaped nozzle.

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Measurements—Industrial and Scientific.

**DR. WALTER BLOCK,** INSTRUMENTS, Vol. 3, No. 8, August, 1930, pages 501-510, 7 figs.

Chapter VI (continued). Measurements of length.

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Handbook of Industrial Instruments.

**M. F. BÉHAR,** INSTRUMENTS, Vol. 3, No. 8, August, 1930, pages 511-528, 16 figs.

Chapter I, Part 5 (concluded). Valve and damper apparatus.

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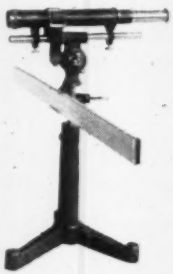

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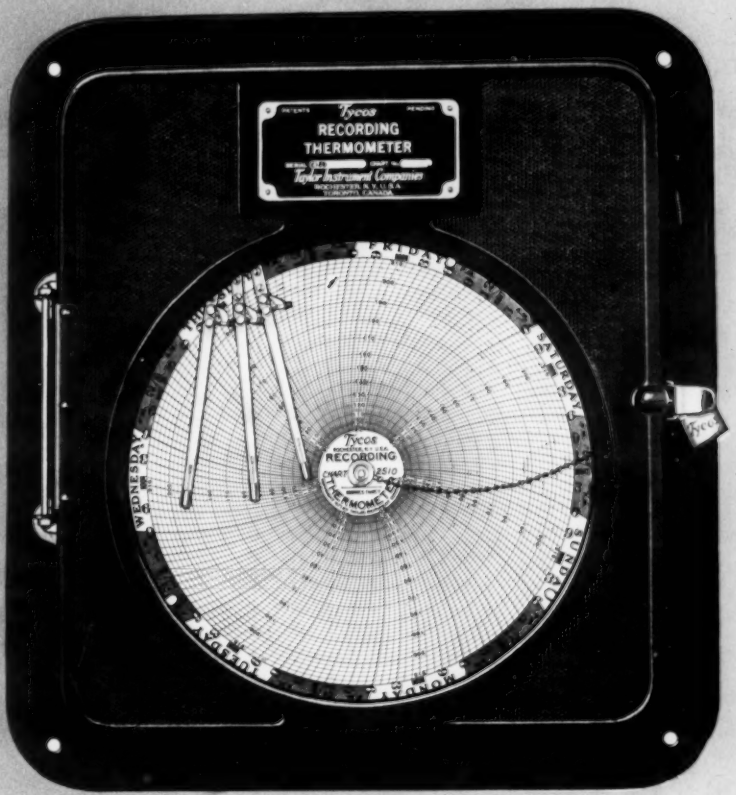


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